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of
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Devoted to Science and the Mechanic Arts

Vol. 185 MAY, 1918 No. 5

FOOD WASTES—SOME CAUSES AND REMEDIES.*

BY

LUCIUS P. BROWN,

Director, Bureau Food and Drugs, New York City Department of Health.
Member of the Institute.

It has been so often repeated in these latter days that "Americans are a wasteful nation" that we have become rather proud of the reproach and apparently have come to glory in our fancied strength in wasting what others must save. Inasmuch as we produce more food per man, though not per acre, than any European country, there has been a certain amount of reason for wastefulness, because it has actually cost us more to save than to waste.

But the outbreak of the great war has raised the price of labor by lessening the supply; it has been withdrawn even from the high-priced lands of Europe; the low-priced and fertile lands of the United States must feed practically all the civilized world with a lessened and ever-lessening labor supply. Well-being is almost coming to be measured no longer in terms of the counters called money, but in pounds of sugar or barrels of flour, because those essentials to the maintenance of life are apparently becoming constantly less abundant in relation to gold. Our days of plenty are gone for many years, and it is quite certain that by the time they return Americans will have so learned food thrift

* Presented at a meeting of the Section of Physics and Chemistry held Thursday evening, January 24, 1918.

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that never again will Nature's gifts be so lavishly thrown about. Aforetime, if persons with a financial competence did not set a lavish table they were "mean and stingy"; now they are exercising the highest form of patriotism. Seriously speaking, however, American wastes of all sorts have been gross, and since now we must follow a different plan, I shall hope to indicate some steps in its beginning.

It will be quite obvious, from a moment's thought, that preventable wastes in foods are almost illimitable in number and kind. They exist wherever food is produced and handled. They will always exist until human nature in the mass undergoes those changes for the better which we all endeavor to compass in our individual lives. They originate in bad farm management, continue in the planting, cultivating, and harvesting of crops, in their transportation, marketing, and wholesale and retail distribution, and in the homes. In this paper we expect to confine our precise inquiry to those which occur in harvesting, in manufacture, in transit and distribution, and in the kitchen—in other words, after the crop has matured.

Table I (pp. 588 and 589) is a partial analysis in diagrammatic form, showing what are probably the principal causes of wastes.

It is a platitude to suggest that this subject is of much more importance to us just now than at any time in the past, or, God willing, at any future time which we here to-night are likely to see. Our 1917 crops were large. They yielded:

	Bushels
Corn	3,159,494,000
Wheat	650,828,000
Oats	1,587,286,000
Barley	208,975,000
Rye	60,145,000
Potatoes	442,536,000
Peanuts	60,222,000
Total	6,169,486,000

Our chief perishables were as follows:

Onions	13,554,000 bushels
Cabbage	502,000 tons
Peaches	45,066,000 bushels
Pears	13,281,000 bushels
Oranges	12,832,000 boxes
Apples	58,203,000 barrels

It is estimated that the Allies should get from some source 577,000,000 bushels of wheat and 674,000,000 bushels of other cereals, or a total of 1,251,000,000 bushels. Competent authority has suggested that 10 per cent. of all crops grown are wasted, which, on the basis of perishables and non-perishables above suggested, indicates that from this source alone, if we were able absolutely to stop waste, we could supply a very perceptible proportion of what is needed.

That this is possible is shown by the application of household economies already forced by high food prices of the past three years. The figures of garbage collected in three boroughs of the city of New York show a reduction for the year 1917 over 1916 of 8 per cent. In Boston, during three months of 1917, as compared with the previous year, there was a reduction of 12.3 per cent., while in New Haven, during 1917, there was an estimated decrease during a part of the year of about one-third. A short study made by me of the actual losses of materials which were good when they went into the garbage pail in New York City gives the surprising figure of $50 per load as the average, ranging from $20.80 to $61. This reduction of garbage, therefore, actually means a saving in money of over one million and a half of dollars. Let us hope that it is an earnest of what we can really do in conservation when we try.

Although not strictly pertinent to our discussion, it will be profitable for us to note some important preventable wastes in production alone, such as the prevalence of cholera in hogs and of tuberculosis and contagious abortion in cattle. Again, it costs one-third less in food and labor to make milk from a high-producing than from a low-producing cow. Akin to the same sort of bad management which maintains the poor cow are such things as the failure to take proper care of a fruit crop by spraying, the raising of poor varieties of fruits and vegetables, bad judgment in the selection of crops for localities and soils, and the like. Most of these are susceptible of reasonably prompt rectification. Correction of the others means that slow process of education and scientific investigation carried on by the Agricultural Colleges' extension work, investigation in the experiment stations, and like activities which already have been so successful.

The layman would suppose wastes of the sort we are discussing are to be expected chiefly or solely in perishables, such as vege-

TABLE I.

Partial Analysis of Food-waste Problem.

Prepared by Lucius P. Brown, Director of Bureau of Food and Drugs, Department of Health, New York City.

WASTES OF FOOD OCCUR IN ITS HANDLING AND UTILIZATION FROM THE FOLLOWING CAUSES.

I. In Producer's Hands	A. On Farm	1. Growing Conditions	a. Unfavorable weather, weakening plant.
			b. Insect pests or micro-organism infection.
		2. In Harvesting	a. Excessive rains or drouth at time of packing.
			b. Shortage of labor.
			c. Too long storage before shipment.
			d. Storage under unfavorable conditions before shipment.
			e. Too early harvesting.
			f. Holding of cars too long because of shortage of labor.
		3. Poor Packing	a. Due to unskilled labor.
			b. Due to shortage of labor.
			c. Rough handling of filled package.
			d. Unsuitable or poorly made containers.
			e. Poor grading.
		4. Shipping Defects	a. Undue holding of cars to secure carload freight rates.
			b. Overloading of cars.
			c. Poor judgment or carelessness in placing packages in car.
	B. From Woods and Waters	1. Catching of young fish.	
		2. Same causes as shown under 1A-2c; 1A-2d; 1A-3d.	
		3. Failure to properly ice.	
	C. In Factory	1. Spoilage from insanitary conditions.	
		2. Spoilage due to unskilled labor or labor shortage.	
		3. Insufficient number or poor quality of containers.	
		4. Failure to use by-products.	
II. In Transit (in hands of transportation companies)	A. At Shipping Point	1. Shortage of cars.	
		2. Congestion on loading trucks.	
		3. Holding at foreign ports for ships.	
	B. In Handling Trains (Domestic Products chiefly)	1. "Slack" Management	a. Poorly designed or improper cars.
			b. See also 1A-4c.
			c. Trains skipping icing stations.
		2. Defects in Handling	a. Refrigeration defective or lacking altogether.
			b. Cars not rendered frost-proof.
		3. Delays in Transit	a. Due to poor management.
			b. Due to strikes, etc.
			c. Due to floods, storms, etc.
	C. In Ocean Transit	1. Damage by enemy boats.	
		2. Use of unsuitable ships or ships without refrigeration.	
		3. Slow voyage because of scarcity or high price of coal.	
		4. Poor stowing in holds, or stowing near boilers.	
		5. Stowing with heating cargo (*e.g.*, sugar).	
		6. Distant markets (with consequent long voyage) because usual markets are shut off by embargo or blockade.	
		7. Damage by marine accidents, such as collisions, fires, leaks, storms, etc.	
		8. Loading or discharge of perishable cargoes under unfavorable weather conditions.	
		9. Damage by transshipment because no direct line to destination.	

II. In Transit (in hands of transportation companies)	D. After Arrival at Destination	1. Congestion at Piers or Other Terminals	a. Due to track shortage. b. From undue length of demurrage. c. Strikes or other labor troubles. d. Due to shortage of storage space for goods.
		2. Ill-advised Reconsignment.	
		3. Undue Holding of Cars	a. Through slack management. b. To profit by market changes (at consignee's order).
		4. Abandoned by Consignee	a. Wholly unsound. b. Partly unsound and overhauling not profitable. c. Partly unsound but facilities to salvage unavailable. d. Market conditions believed to be unfavorable.
		5. Rough handling at terminals.	
III. In Distribution (from hands of transportation company to consumer)	A. Wholesale	1. Holding too long.	
		2. Inefficient care.	
		3. Poor storage facilities.	
		4. Goods stored in poor condition.	
		5. Overstocking.	
		6. Damage by rats, insects, etc.	
		7. Failure to remove promptly from terminals.	
	B. Retail	1. Carelessness or inefficiency.	
		2. Through fancies of customers.	
		3. Due to trimming, etc.	
		4. Overstocking.	
		5. Exposure to dust and insects.	
IV. In Kitchen	A. Hotel or Restaurant Kitchen	1. Stale bread thrown away.	
		2. "Slack" business methods.	
		3. Portions too large and too many gratis "side-orders."	
		4. Too much variety in dishes or single items, *e.g.* bread.	
		5. Overstocking.	
		6. Influence of custom, *e.g.* serving sugar on table.	
		7. Improper disposal of waste products, *e.g.* burning of garbage.	
		8. "Aging," and consequent loss in trimming, of meats.	
	B. Private Family	1. Unbalanced ration.	
		2. Letting good food go into garbage pails and sinks.	
		3. Poor facilities for and ignorance in handling foods.	
		4. Poor cooking.	

Wastes in the Food Supply, due to Economic Reasons and resulting therefore in loss of money to the consumer, occur in Trade Channels in part from the following causes:

A. No Terminal Markets.
B. Duplication of Marketing Facilities.
C. Expensive Cartage.
D. High retail delivery costs.
E. Unnecessary credits.
F. Extravagance in service and display.
G. Failure to buy home-packed goods of equal quality.
H. Failure of retailer to use proper merchandising methods.

tables, fruits, and eggs, but they are surprisingly large in the more stable foods, such as cereals, beans, etc.

As a somewhat extreme instance of poor marketing methods with resultant loss, it will pay us to follow closely what happens to eggs, in order to get the principles in our minds. It is estimated that the actual annual loss of eggs in the United States is about $50,000,000, or about two billion eggs, which means 20 eggs for every man, woman, and child in the United States. New York City's record will bring the matter to less overwhelming and therefore more understandable figures. The city's annual receipts are 5,000,000 cases, or 150,000,000 dozen. Breakage alone, due to shipment, is about 3½ per cent., which is 5,250,000 dozen, or about enough to furnish each inhabitant of the city with one egg for breakfast once a month. Inasmuch as this waste has not been stopped, neither I nor most of my friends have been able to have our monthly breakfast egg of late. That this is not a loss to the consumer and distributer alone is shown by the fact that at an Interstate Commerce Commission hearing held in the city in 1915 it was shown that the receiver's claims for breakage varied, on one of the railroads, from 8 to 60 per cent. of the monthly gross revenue from the business.

Loss in eggs begins before laying, for, if the farmer fails to separate his male birds from the laying flock, the eggs are fertile. A fertile egg begins to spoil at 70° F., because the life processes begin at that temperature, and an infertile egg will, under those late spring and summer temperatures which are so fatal to the egg supply of the South and Southwest, keep 10 to 20 days longer than the fertile one.

Remembering this, let us follow our trail of the egg. Of course, much the larger proportion of the supply comes from those farms where it is an incident to the general business. Usually the collections are made daily, but even then a very large proportion is from stolen nests in the fence-corners or the haymow, and in such event even daily collections furnish eggs of a varying vintage. The farmer's wife sells either to the travelling pedler or huckster or to the village store. In either case there is a certain amount of holding, and sometimes such holding (which is never under refrigeration) is in the hope of higher prices, and for as long as six weeks. The travelling collector is usually an agent or patron of the produce dealer in one of the larger towns.

His problem is not so much one of finding a market as of getting a supply. He is therefore loth to test his eggs by candling, because he does not care to risk the displeasure of the farmer's wife and so the loss of his farm supplies. In setting his purchase price, knowing as he does the losses he may expect, he makes an average figure such that the sound eggs of the careful and honest woman bring the same price as those of the other kind—which is the beginning of the actual money loss. There is some breakage before he gets his load to the produce dealer and (especially if he strikes a spell of hot weather) loss from spoilage, for his round trip rarely lasts less than a week. If, on the other hand, the eggs are taken to the country store, the transaction is mostly one of barter. Though the merchant has a double chance for insurance, he still needs doubly the business of the woman producer and applies the same principles as the huckster. The country merchant holds the eggs in a tub or box in the back of the store until it is convenient to ship by rail or road, resulting again in breakage and spoilage. He, too, trades with a produce dealer in a large town. The latter, if he is careful, candles for quality and sorts as to appearance. Thence the eggs go in car or smaller lots to the large consumption points, where they receive a final sorting: the cracked and dirty eggs are taken out, as well as the really unsound ones; sometimes they are even sorted according to color, for apparently a brown egg agrees with the digestion of Boston better than with that of New York. The final consumer's product, of course, bears most of the cost of all this, for the demand for off-grades is of a less stable character and at a necessarily much lower price. All this trouble, too, forces minor expenses to be paid out of the business, such as the additional cost imposed by careful sorting, the costs imposed on trade associations in efforts to stabilize the business and regulate the careless or dishonest dealer, as well as costs to the community imposed in enforcing food laws controlling the wholesomeness of the product. It is estimated that the losses in the various hands are distributed about 50 per cent. to the producer, while the shipper, the carrier, and the distributer divide the rest.

Fortunately for the foodstuffs trade in general, the handling of most perishables is either not so complicated as this or has become better systematized. The usual course for goods grown in the United States is from the farmer to the commission man

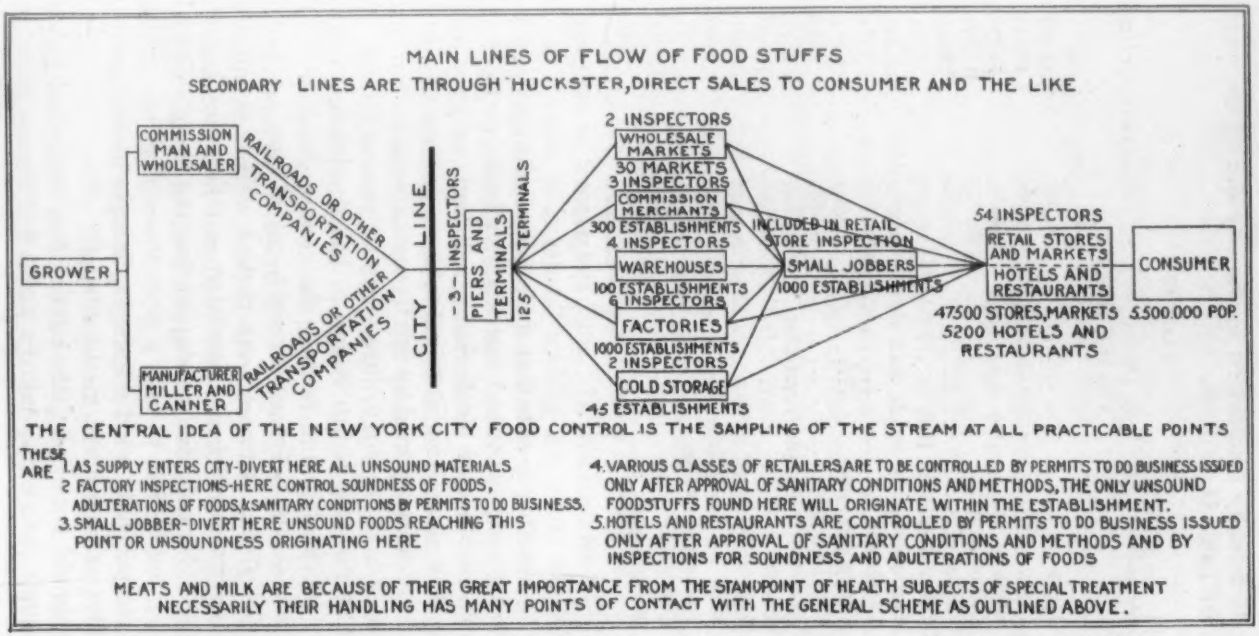
or wholesaler, thence to the small jobber, to the retailer, and to the consumer or restaurant, and it is essentially under these heads we shall make our examination.

Wastes in the purely marketing end of the business cannot be better illustrated than by the experience of the New York City Health Department's Bureau of Food and Drugs under its recently inaugurated system of inspection. This bureau is charged with the duty of controlling the quality and purity of the food supply of that city, and in order to do this most effectively it has considered the food supply as a stream and examines this stream at every available point from producer to consumer. Obviously, in the case of a city, it can, as a practical proposition, go back to points of production only in the case of certain commodities having a very direct public-health bearing, such as milk. It therefore begins with the sampling of the food stream as the food comes across the city line, according to the scheme shown in Fig. 1. The force for inspection is subdivided into a number of districts, somewhat on the plan of police precincts, and, in addition, there are squads assigned to special work. There are two permanent squads, one of which is assigned to the railway and steamship terminals (which means, in New York City, largely the piers on the Hudson and East rivers, both in Manhattan and Brooklyn) and the squad assigned to control of factories. The duty of the Terminal Squad is to prevent unsound or damaged foods from entering the city, and of the Factory Squad, which has charge also of warehouses, to see that unsoundness originating within the city is properly controlled. The Terminal Squad is instructed whenever unsound material is found to inquire into the reasons for this unsoundness and to make a report thereupon with a view to correction of conditions through advice to shippers or transportation companies.

It is illegal for unsound food to come into the city. Therefore, when a lot wholly unsound is found, it is at once condemned and ordered destroyed; a lot partly unsound is placed under embargo and the holder is ordered to separate the sound from the unsound portions. Price levels will then determine whether the holder will carry out this order or abandon the goods to be destroyed.

I cannot better indicate to you the extent of preventable losses than to call attention to the table of the kind, amounts and values

FIG. 1.


MAIN LINES OF FLOW OF FOOD STUFFS
SECONDARY LINES ARE THROUGH HUCKSTER, DIRECT SALES TO CONSUMER AND THE LIKE
GROWER
COMMISSION MAN AND WHOLESALER
MANUFACTURER MILLER AND CANNER
RAILROADS OR OTHER TRANSPORTATION COMPANIES
RAILROADS OR OTHER TRANSPORTATION COMPANIES
CITY LINE
3 INSPECTORS
PIERS AND TERMINALS
125 TERMINALS
2 INSPECTORS
WHOLESALE MARKETS
30 MARKETS
3 INSPECTORS
COMMISSION MERCHANTS
300 ESTABLISHMENTS
4 INSPECTORS
WAREHOUSES
100 ESTABLISHMENTS
6 INSPECTORS
FACTORIES
1000 ESTABLISHMENTS
2 INSPECTORS
COLD STORAGE
45 ESTABLISHMENTS
INCLUDED IN RETAIL STORE INSPECTION
SMALL JOBBERS
1000 ESTABLISHMENTS
54 INSPECTORS
RETAIL STORES AND MARKETS
HOTELS AND RESTAURANTS
47500 STORES, MARKETS
5200 HOTELS AND RESTAURANTS
CONSUMER
5,500,000 POP.
THE CENTRAL IDEA OF THE NEW YORK CITY FOOD CONTROL IS THE SAMPLING OF THE STREAM AT ALL PRACTICABLE POINTS
THESE ARE
1. AS SUPPLY ENTERS CITY-DIVERT HERE ALL UNSOUND MATERIALS
2 FACTORY INSPECTIONS-HERE CONTROL SOUNDNESS OF FOODS, ADULTERATIONS OF FOODS, & SANITARY CONDITIONS BY PERMITS TO DO BUSINESS.
3. SMALL JOBBER-DIVERT HERE UNSOUND FOODS REACHING THIS POINT OR UNSOUNDNESS ORIGINATING HERE
4. VARIOUS CLASSES OF RETAILERS ARE TO BE CONTROLLED BY PERMITS TO DO BUSINESS ISSUED ONLY AFTER APPROVAL OF SANITARY CONDITIONS AND METHODS, THE ONLY UNSOUND FOODSTUFFS FOUND HERE WILL ORIGINATE WITHIN THE ESTABLISHMENT.
5. HOTELS AND RESTAURANTS ARE CONTROLLED BY PERMITS TO DO BUSINESS ISSUED ONLY AFTER APPROVAL OF SANITARY CONDITIONS AND METHODS AND BY INSPECTIONS FOR SOUNDNESS AND ADULTERATIONS OF FOODS
MEATS AND MILK ARE BECAUSE OF THEIR GREAT IMPORTANCE FROM THE STANDPOINT OF HEALTH SUBJECTS OF SPECIAL TREATMENT NECESSARILY THEIR HANDLING HAS MANY POINTS OF CONTACT WITH THE GENERAL SCHEME AS OUTLINED ABOVE.

Sketch of system for control of food supply as used by the Bureau of Food and Drugs, Department of Health of New York City.

of foods actually condemned in the city during the year 1917, shown in Table II.

TABLE II.

Condemnations of Foods During 1917 by Department of Health, City of New York.

	Amount (pounds)	Cost
Meat	538,531	$115,409
Fish	362,280	18,644
Fruit	1,482,865	74,438
Citrus fruit	5,862,842	316,200
Grapes	1,001,080	78,947
Other deciduous fruit	143,093	1,545
Pineapples	645,755	51,449
Vegetables	2,804,657	55,374
Coffee and spices	708,035	105,854
Canned goods	302,782	8,253
Assorted fruits and vegetables	272,643	13,632
Nuts	224,468	21,630
Eggs	4,640	2,784
Milk	1,838	110
Butter and cheese	2,165	866
Confectionery	118,785	17,818
Miscellaneous	58,251	4,923
Total	14,534,710	$887,876

It is interesting to note that the condemned food in New York City during 1917 contained nutrients sufficient to have fed for the whole year one of Uncle Sam's regiments of 3775 men.

It will be interesting and profitable to go into the details of some of the cases reported by this Terminal Squad. For instance, on June 28 and 29, 1917, three cars of potatoes from Florida arrived at Pier 28, North River, in bad condition. They were ordered overhauled, and because the commission-merchant consignee refused to overhaul promptly all of one car had to be destroyed. These potatoes were packed while wet into double-headed barrels, insufficiently ventilated, and therefore heated while in transit. Not only did the shipper lose the barrels which were destroyed, but he had to take a price lower than the market for subsequent perfectly good shipments, because buyers were afraid of his line, as he advised me in a letter.

We should not expect this kind of loss in canned goods, but 6500 pounds (164 cans) out of a carload of tomato paste, packed

in 5-gallon cans, was found on November 10, at Pier 28, in bad condition. These cans had been placed in the car without being crated and without braces or boards to prevent shocks in shipment. The consequence was that the cans in the lower tiers parted at the joints from the weight on them, and a large number of the others were punctured as a result of improper stowing while in shipment.

Marrons, or so-called Italians chestnuts, are now being shipped in large numbers from Spain and Portugal. There is a large accumulation of these nuts awaiting transportation, and the United States appears to be the chief, if not the only, market. The ships are ill-ventilated, when any ships at all are available, and run slowly, because of the high price of coal. It has been found necessary to embargo almost all shipments received this season because they are heated, and the total condemnations amount up to date to more than 2,000,000 pounds. This is one of the classes of waste which it is almost impossible to prevent under present conditions, because of disturbances produced by the war. The same thing is true of a recent condemnation of some 19,000 barrels of Spanish grapes.

An instance of actual conservation is involved in the case of 1300 boxes of lemons last June. In this instance the owner was prevailed upon to overhaul, making an actual reduction of his loss by $281, while an analogous instance is that of 29 barrels of potatoes received in July which were turned over to the city salvage kitchen, and the 24 barrels of potatoes recovered sold at a price of one cent per pound. Another instance on the same day showed that the spoilage of 87 bags of potatoes out of a lot of 250 was due to the fact that early potatoes were shipped in burlap bags, when they should have been shipped in ventilated barrels. This was the farmer's fault; and another case where the farmer made a mistake occurred the following month, in which a shipment of 200 barrels from Virginia was left after digging exposed to rain, followed by sun, packed when thus heated, and then were allowed to stand on the loading tracks for several days, awaiting a track-buyer.

A loss due to poor judgment of the best marketing point is exemplified by the large shipments of cucumbers to the New York market during the week ending July 1, resulting in a market glut. After sending about 10,000 pounds to city institutions,

100,000 pounds additional were dumped upon the Jersey meadows because there was no sale for them at any price and they had become or were becoming unsound.

During the week beginning August 24 there arrived at the Spanish Line Pier in Brooklyn 125,000 pounds of onions, partly unsound, and the consignees refused to overhaul them and pay the duty. Forty-odd thousand pounds could have been saved by volunteer workers but for the fact that the Federal Government refused to waive demand for duty on the sound portions.

For the past year there has been an excellent market for beans at high prices, the result being that large shipments have come in from South America, India, Manchuria, etc. Some of these beans, particularly those from South America, are infested with eggs and larvæ of certain weevils. On storage these develop, and the infestation spreads from the original proportion of three or four per cent. of the lot to fifty per cent. and more. These flies are impartial in their tastes and will infest other lots of beans in the same warehouses, whether of domestic or foreign origin. The losses within the last twelve months from this cause run to millions of pounds, and there is in addition the grave danger of introducing such dangerous pests into our own fields. All this can be prevented by prompt fumigation of the beans on receipt. No government agencies up to this time have had laws to proceed under to compel such fumigation, although the city requires that they be fumigated and made sound before actually entering trade.

Typical instances of this sort could be multiplied. It will be noted that almost everything that I have quoted is preventable. It is particularly desirable, however, to call attention to the importance of suitable and strong containers, the failure to use which has caused so large a proportion of loss. This feature, as well as the importance of proper stowing in the cars, is shown by Figs. 2 to 11, which likewise illustrate the saving of space, rolling stock, and motive power which may be effected by proper stowing and bracing of the load, and by using the full capacity of the car. The descriptions under each plate tell the story well.

Another most important cause of loss is the failure to properly grade and pack. Only in a few sections is this thoroughly understood by the producer. Farmers habitually load potatoes "field run," "plate" barrels of apples (putting the "baby" sizes in the middle), load specked goods with sound and the like. Failure

FIG. 2.

A poorly packed car of cucumbers on opening. Note crushed baskets. (New York City Department of Health.)

FIG. 3.

Peach baskets crushed because no shelving was provided in car to keep weight off bottom tiers. (U. S. Department of Agriculture, Office Markets.)

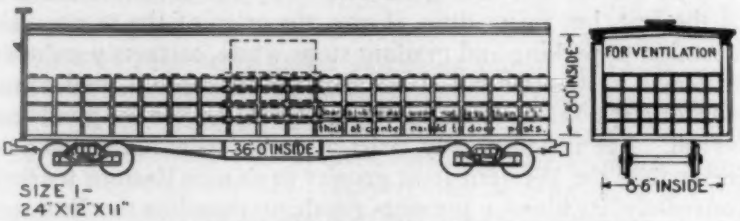
FIG. 4.

Potatoes in cloth-top barrels stored in car three high, *on bilge*. They should be stored on ends. The stupidity of this method of loading is apparent. (U. S. Department of Agriculture, Office Markets.)

FIG. 5.

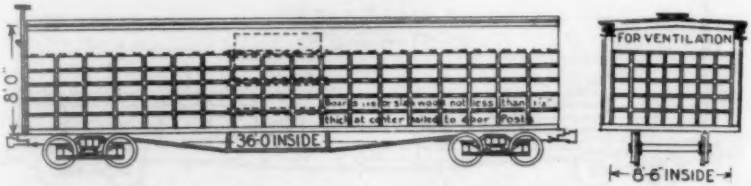
Crates of cabbage properly loaded and braced in car. (U. S. Department of Agriculture, Office Markets.)

FIG. 6.



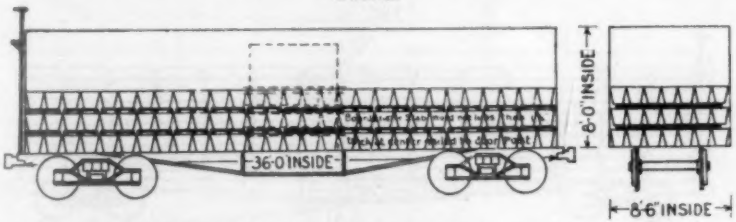
Fresh tomatoes in crates. Ordinary method of loading. Five hundred crates per car, weight 20,000 pounds. Note waste of space.

FIG. 7.



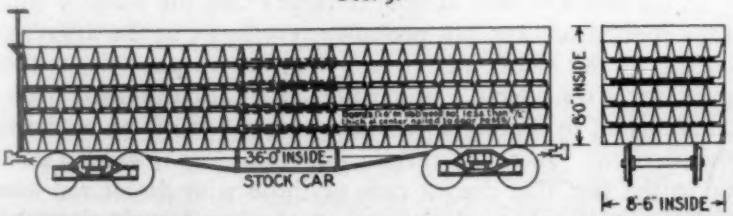
Fresh tomatoes in crates. Approved method of loading by adding an additional layer of crates, increasing capacity of car by twenty-five per cent.

FIG. 8.



Fresh tomatoes in hampers. Average load, 609 hampers (27,000 pounds). Wastes forty per cent. cubical capacity of car.

FIG. 9.

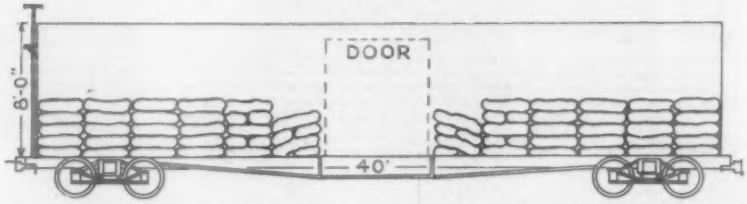


Approved method of loading fresh tomatoes in hampers—1015 baskets (46,000 pounds), utilizing full cubical capacity of car. The small additional labor and lumber costs involved will increase carrying capacity of rolling stock by two-thirds, or an equivalent of sixty-seven per cent. greater number of cars, and ending waste from tomatoes rotting on ground through lack of shipping capacity.

NOTE.—I am indebted to the Pennsylvania Railroad Company for permission to reproduce Figs. 6 to 11.

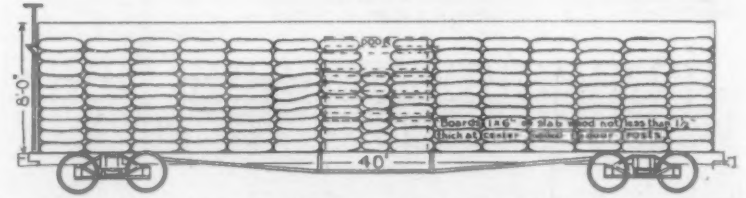
to separate the different grades not only brings down the price of the best, but raises little, if any, the price of the worst. Due attention to packing and grading stops waste, attracts purchasers, enables a systematic use of unmarketable material, and always assures a market through making a reputation for the goods concerned. For instance, only strict attention to grading and packing enables the Western fruit grower to ship to Eastern markets; conversely, its absence prevents goods produced in the East, as a rule, from seriously competing with the attractive Western stock.

FIG. 10.



Loading of sugar according to old selling standards. Car load unit, 400 bags (40,800 pounds). Note extreme waste of car space. This illustrates one of the old bad trade customs which should not have waited for war conditions to be broken up.

FIG. 11.

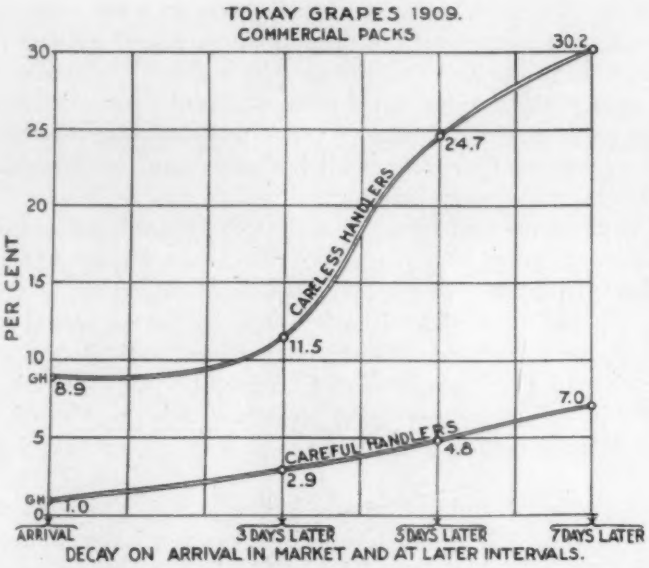


Approved method of loading cars with sugar—1000 bags (102,000 pounds), utilizing full cubical and weight-carrying capacity of car.

In the retailer's end, at least in large cities, the waste is small, in the individual case, but probably very large in the aggregate. Neglect of the stock, and overbuying, are responsible, without doubt, for a considerable proportion of it. Sound open stock is contaminated by failure to remove unsound stuff, or by rats or other vermin. There is a certain amount of loss in canned goods, due to the fact that dented cans or those with discolored labels are less salable (although the contents are unaffected) than those with a nice appearance, and are therefore destroyed. In certain poor sections of the large cities food is sold in very small portions, such as a quarter of a loaf of bread; the cut unsold portion which remains overnight is unsalable. Early in the season or in times

of frosty weather the retailer receives potatoes in bad condition, necessitating sorting by him. There is considerable loss in fish because of poor icing and a failure to utilize the heads, napes, and fins for chowder or flavoring purposes. Consumers' demands, however, are probably responsible for the largest loss here. Fancies of customers are responsible for failure to utilize a great deal of material, and the waste of time and money due to the demand for delivery service is of paramount importance.

FIG. 12.



Showing difference between results of careful and careless commercial packs of Tokay grapes. (U. S. Department of Agriculture, Office Markets.)

The largest wastes of all, however, appear to occur in the utilization of food in the kitchen, whether this be in the private family or the restaurant. A short survey made in New York under my direction in July, 1917, of the amount of food thrown into the garbage pail shows how much we actually throw away. Garbage varies greatly in its composition, and the amount of waste will vary with the race of the consumer, with the actual price of foods, and with the scale of living. Even giving all due allowance to these limitations, this survey is very illuminat-

ing. It was made by accompanying the garbage collectors on their rounds, sorting out, estimating, and listing the kind and amount of food found in the garbage cans. Some 27 per cent. of material was found which was apparently fit for use when thrown into the garbage pail, giving an average value per pound of the whole of 2½ cents, or $50 per ton load. If the amount and value of this be discounted 20 per cent., we reach the huge sum of $15,945,520, or a value sufficient to buy food for 136,520 people for a year. Of this waste, about one-third is bread and about half as much is meat, the rest being vegetables, beans, etc. The waste is, of course, greatest in well-to-do sections, and there is little waste by the poorer families, in whose case it consists mostly of vegetable tops and trimmings which the French would use. The redeemable values vary from 1.4 cents per pound in the poorer sections of the city to 3.5 cents in the more well-to-do. The medium wage-earner, the small business man, or the rich man appears to be the worst offender.

I have mentioned bread above. On the basis calculated, the waste for the city in a year would be about 60,000,000 pounds of bread, equivalent to 964,287 bushels of wheat or 0.18 bushel each, which if applied to the whole United States, would give us a waste of 19,800,000 bushels per annum, and this applied to the eight months from January to September, 1918, would make quite a hole in the 90,000,000 bushels which the United States Food Administration tells us we must send to our Allies in that period.

In the hotel and restaurant kitchens and dining-rooms the efforts made to attain efficiency in operation have been greatly promoted by the high cost of food during the past three years. This, however, does not apply to the usual run of "American plan" hotels, in which the absolute wastes of food are nothing else than shocking. In these places the amount of uneaten food is probably quite as large as, or larger than, that which is eaten, and, inasmuch as when once served there is no way of knowing whether it has been touched by the patron, there is no means of redeeming it, and it must all go to the garbage pail. Real wastes found by actual inquiry have been found to be most largely in succulents and green foods; the outside of the heads and the tops and trimmings of such stuff as radishes, beets, and asparagus are very seldom utilized, although in a few places they are used for salads or

soup stock. There is little or no waste in meats and fish, except for the returned portions.

At the period of investigation some six months ago a good deal of butter was used for frying purposes. It is to be expected and hoped this is now substituted by cheaper fats. Without rather exhaustive work, it would be difficult to ascertain the exact amount of real waste in restaurants. The opinion of one steward,

FIG 13.

Pier 29, Pennsylvania Railroad, New York City, showing crowded condition during shipping season. (New York City Department of Health.)

who acknowledged that he had nothing to base it upon, was that unavoidable wastes were 15 per cent. This furnishes at least something to hang judgment on.

One sin of which some hotels are unquestionably guilty is the burning of garbage as the easiest way to get rid of it. It should, of course, be utilized for its fat and feeding value for animals. The hotels apparently have much to answer for to the Food Administration, if we are to credit the newspaper reports

which indeed are confirmed by the observation of all of us who have occasion to deal with them. Their offences are based on a desire to get and keep business. Here again the customer is responsible, and we have to condemn the hotel proprietors possibly for nothing else except lack of "backbone" and a failure to get together among themselves so as to eliminate unfair competition.[1] Our own investigations in New York last summer showed that there are entirely too many side orders and side dishes served, the portions were unnecessarily large, there was a great waste of the expensive and necessary milk, butter, cream, and eggs in the making of fancy pastry, and at that time there was an enormous waste of bread, which was sold, after becoming one day old, for hog and chicken feed. The latter practice has now practically been stopped, I believe.

The more intangible losses in the home kitchens due to unbalanced rations, to poor cooking, and to the lack of a proper system in the kitchen are probably very much larger than the wastes in garbage, but there is no means of accurately estimating them at hand; the United States Department of Agriculture's Division of Home Economics places them at a money value of $700,000,000.

From a war-time standpoint there is an enormous waste of foods predicated by the mere existence of non-essential food industries. It can hardly be said that the great number of candy shops serve any other urgent economic need than that of an occasional physician. Soda-water and other soft-drink stands absorb, in the aggregate, an enormous amount of food without, so far as we can see, making any notable contribution to the national nutrition.

Condiments have a recognized value in the dietary, but it is open to question whether their use is not excessive, and certainly when their preparation involves the consumption of materials which can just as well be used whole, their free manufacture should be questioned. Thus there are more than a ton of eggs a day used in New York City for making mayonnaise dressing. It is desirable to avoid drastic and sudden interference with non-essential industries, but we cannot escape the conclusion that their

[1] Since this was written the efforts of the Hotel Division of the U. S. Food Administration appear to have been productive of such improvement as to remove most of the reason for criticism.

output should be decreased gradually to a point where there is not serious interference with those industries with which we cannot dispense.

It is stated that the Food Administration desires the passage of a bill extending its powers so that it may enforce its orders on places of public entertainment and in other quarters where enforcement cannot now be had. Not only should such power

FIG. 14.

South Water Street, Chicago, at a busy hour. This shows waste in double hauling from terminal to warehouse and then to retailer. Every large city can duplicate this scene. (U. S. Department of Agriculture, Office Markets.)

be given at once, but if the power does not now exist to punish both public and private consumers for wilful wastes, that power should be conferred. It has been freely used in England and appears to have been of value there.

Losses in foodstuffs produced by a defective economic system of marketing are difficult to estimate accurately. I have already suggested certain of those which have both physical and economic aspects, such as careless packing, poor grading, delays in transit,

etc. Those which may be said to be of a purely economic nature are in part as follows:[2]

(*a*) In marketing at country points: Lack of knowledge of market conditions and of prices, on the part of farmers; an unnecessary number of local buyers; abuse of monopoly power when there is only one buyer and of price agreements when there are several buyers; poor business management; poor roads.

(*b*) In the wholesale trades: Opportunity for sharp practice and fraud; lack of adequate inspection system; lack of adequate price-quotations system; insufficient means of procuring and disseminating information on crop and market conditions and crop movements; lack of uniformity of methods, customs, grades, packages, etc., as between different markets; control of auction companies by cliques, etc.

(*c*) In the transportation end: Ill-adjustment of rates between localities and between commodities; lack of uniformity in making adjustments of claims for damage; unfair icing charges, etc.

(*d*) In the retail system (which is, according to Weld, the most expensive element in the marketing system): Dishonesty in weights and misrepresentation as to quality; overstocking; too little credit; delay in payment for goods bought from wholesalers; unnecessary duplication of delivery and other equipment and services.

The retailer, likewise, is not to be charged with all the excessive costs in his business. The desire of consumers for expensive service, including prompt delivery of small orders, is one of the most fruitful causes of waste motion in food distribution.

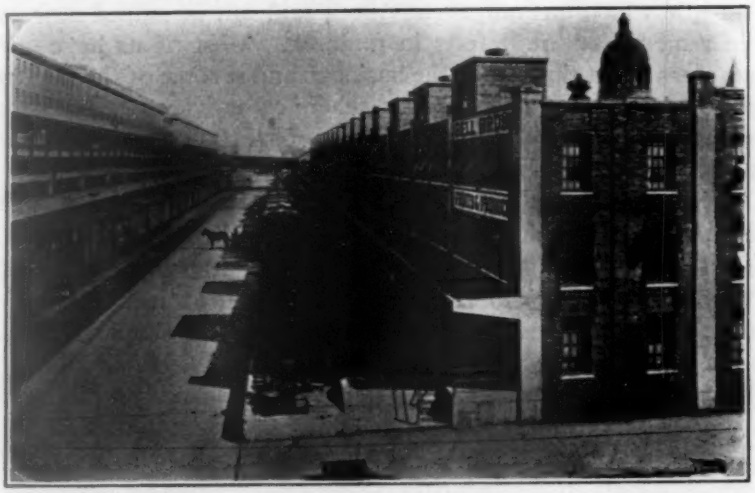
When we come to consider the question of remedies, we must bear in mind that the deficiencies, physical and economic, are both very numerous and of great diversity, and that we have had time here to consider only a small part of them. There is no simple panacea which can be applied, nor will any single revolutionary process help us. Weld suggests that the economic, and

[2] L. D. H. Weld, "The Marketing of Farm Products," ch. xxi.

probably a large part of the physical, wastes may be remedied broadly under four classifications, to wit: First, coöperation among farmers and among consumers; second, associative effort on the part of middlemen; third, education; fourth, governmental regulation. For losses at the farm, educational means concentrating on grading and packing are of particular importance.

Farm labor is scarce, and to this condition the new Labor Supply Bureau of the Federal Government will afford at least a certain measure of relief. For losses in transportation, that

FIG. 15.



Wholesalers' stores owned by railroad, and goods unloaded at rear. Saves unnecessary handling and carting. (U. S. Department of Agriculture, Office Markets.)

coördination of the railways which ought to follow Federal operation will greatly reduce difficulties. Two points are of particular interest here; namely, that city terminals now used to only partial capacity by one or two systems will be available to all railroads, resulting in prompter deliveries and in shorter hauls by receivers, and that we should expect, likewise, to see a cessation of the practice of holding loaded cars for a rise in the market or for use as warehouses.

For goods which have actually become partly unsound a certain amount of salvage can be had by turning over to associations

of volunteer workers in the large cities, for the application of preservative processes, such as canning, or who may sell direct at a reduced price to consumers. Labor costs in salvaging are, in this way, eliminated, and the goods should cost such volunteer agencies nothing. Another method of utilizing goods thus abandoned by the consignees would be through turning them over to those parts of the city government charged with the buying and selling of food or to public or private charities. In applying such methods of salvage to imported foods, the matter of claims of the Treasury Department for duty must not be overlooked, and on goods not sold for profit the duty should be remitted.

Little which has not already been said can be named now as to a remedy for the defects in retailing. Most of us have our own ideas about this end of the business, and if some of them were applied by each one of us in our sphere of activity as customers we should unquestionably make some progress. But most people are quite willing to let somebody else apply such remedies.

There is one method of conservation of food materials which deserves a paragraph to itself. This is the dehydration of foods, so extensively practised before and since the war with Germany. There are apparently more than two thousand of such establishments now in operation in that country. The simple process is one which was extensively used on a household scale all over the world before the great development of canning within the past fifty years and which is still practised in remote districts. There is, therefore, no question as to its practical character. It consists merely in the reducing of the sound fruits or vegetables to suitably sized pieces and the subjecting of this material to hot air, combined, for the most satisfactory products, with an atmosphere of moderate humidity.

In connection with a patriotic woman of New York City, the Health Department of that city did much work last summer with a view to developing a practical method for dehydration. The results showed that the cost was reasonable, the product left little to be desired, and when reconstituted was for most purposes fully the equal of fresh material. Speaking broadly, the advantages to be derived from a development of dehydration in the United States are as follows:

(*a*) The utilization of surplus now remaining in growing districts, which, for one reason or another, cannot be shipped in fresh condition, such reasons being chiefly too rapid ripening for the market to absorb, difficulty of obtaining labor, and unfavorable weather conditions preventing shipment.

(*b*) A very considerable development of the consumption of vegetables in America, thus relieving the present defective character of our dietary in this respect as compared with that of European nations.

(*c*) Consequent increase in production of vegetables.

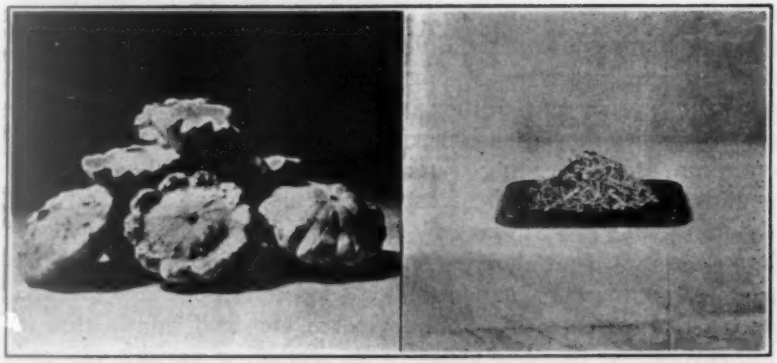
(*d*) And proceeding from these, a lesser consumption of stable foods, such as grain, meats, etc.

(*e*) A possible lessening of the demands on the railroads for weight and car space to haul fresh vegetables, which contain from 75 to 95 per cent. of water.

(*f*) Finally, the enabling of purchase by the poor in the cities of vegetables the year round.

The chief difficulty in the way of the growth of the industry is the fact that there is at this time no market in civilian life ready

FIG. 16.



Dehydration of vegetables. The small pile shows the size of the large pile of squash after drying. The same thing happens with all other vegetables. Note great saving of space.

to take its products. This need not, however, deter persons who may be thinking of developing it because, for any amount which can be produced within the next two or three years, the American

and allied armies will furnish more demand than can be possibly supplied. The French Army uses about one-half pound a day of this material per man, the Germans even more, both of them in the form of soups and stews. Certain elements in immigrant American life make of such prepared dishes a large part of their dietary, and no great educational campaign would be necessary to induce a considerable buying movement among these people. An important "talking point" to encourage use is that the preparation of the vegetables is all done before dehydration, thus relieving the housewife of that tedious and none too pleasant job.

It is further to be said that during the past season farmers and truck growers did their whole duty in increased production, particularly of perishables, a comparatively large part of which consumers were unable to utilize, and there was much complaint of these crops going to waste, throwing unwarranted loss on producers. It is the simple duty of the rest of the country to supplement these agricultural efforts by the establishment of small low-cost dehydrating units near points of production. They can be most profitably located in combination with canneries, mills, or any other manufacturing units furnishing buildings and power.

Time does not allow of treating in detail certain most important changes having at once economic, agricultural, manufacturing, and dietary factors. C. L. Alsberg has well called attention to these: Quoting Farmer's Bulletin No. 629, he notes the fact that only 3.4 per cent. of our corn crop, $^{9}/_{10}$ per cent. of our oats, and $^{7}/_{10}$ per cent. of the barley goes into human food—a purpose for which they are all largely used in other countries; that the optimum use of feeding-stuffs has been made by hogs at 150 pounds weight and by beef cattle at 6 months of age, and they should then be killed; that 27½ per cent. of the milk supply goes into skim-milk (our cheapest source of animal protein), which is now fed to animals; that too much foodstuffs goes into the arts, such as for starch, sizing, foundry-cores, etc., and, finally, that we utilize nothing like our capacity in producing various oil-seeds which would prevent our suffering from that fat-hunger which, rather than protein-hunger, has produced the greatest hardship in Germany. The whole subject is one of such infinite variety that only single aspects of it can be touched upon within the limit of one paper.

PHYSICS OF THE AIR.*

BY

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CHAPTER XIII.

FOGS AND CLOUDS.

THE deposition of dew, the forming of hoar-frost, and the sweating of ice pitchers, all examples of surface condensation, show that atmospheric moisture promptly condenses upon any object whose temperature is below the dew-point. Similarly, volume condensation takes place in the form of a fog or cloud of innumerable droplets, or ice spicules, throughout the body of ordinary air whenever by expansion or otherwise it is sufficiently cooled. But this is not equally true of all air. Thus, while the first considerable rapid expansion, and therefore decided volume cooling, of humid air in a receiver, if recently admitted unfiltered, is quite certain to produce a miniature cloud, subsequent expansions of the same air produce fewer and fewer such particles. If the old air is removed and unfiltered fresh air admitted, the condensations again occur as before; but if the fresh air enters through an efficient filter, such as a plug of cotton wool a few centimetres long, condensation remains as difficult as in the exhausted air. The admission, however, of a little smoke restores to the exhausted and confers upon the filtered air full powers of condensation.

Obviously, then, cloud droplets form about nuclei that cannot easily pass through mechanical filters of fine texture, and microscopic examinations of the residue left on the evaporation of these droplets have shown the nuclei to consist in large measure of dust particles, both mineral and organic. Hygroscopic gases, such as the oxides of sulphur and of nitrogen, may also act as condensation nuclei, but ordinarily there is abundant dust in the atmosphere (thousands of particles per cubic centimetre) to provide for all precipitation. It is often urged that free electrons in the air

* Continued from page 538, vol. 185, April, 1918.

also act as nuclei about which water vapor condenses, but, as this type of condensation requires about a fourfold supersaturation, its occurrence in the open seems extremely improbable.

As stated, volume condensation may be induced in the atmosphere by any cooling process: whether by radiation, as on clear nights; mixing warmer with colder masses of air; movement of relatively warm air over cold surfaces, as in the case of winter south winds (northern hemisphere); or expansion, owing either to convection or barometric depression. But the cooling process has much to do with determining the extent of the condensation, the kind and amount of precipitation from it, and its general appearance, according to which, chiefly, it is classified.

Distinction Between Fog and Cloud.—Volume condensation is divided primarily into fog and cloud, but a sharp distinction between them that would enable one always to say which is which is not possible. In general, however, a fog differs from a cloud only in its location. Both are owing, as explained, to the cooling of the atmosphere to a temperature below its dew-point, but in the case of the cloud this cooling usually results from vertical convection, and hence the cloud is nearly always separated from the earth, except on mountain tops. Fog, on the other hand, is induced by relatively low temperatures at and near the surface, and commonly itself extends quite to the surface, at least during the stage of its development. In short, fog consists of water droplets or ice spicules condensed from and floating in the air near the surface; cloud, of water droplets or ice spicules condensed from and floating in the air well above the surface. Fog is a cloud on the earth; cloud a fog in the sky.

FOGS.

According to the conditions under which they are formed, fogs may be divided into two general classes—radiation fogs and advection fogs.

Radiation Fog.—Fog is likely to form along rivers and creeks and even in cleared mountain valleys during any still, cloudless night of summer and, especially, autumn. In the course of a calm warm day much water is evaporated into the lower atmosphere of such regions, where in large part it remains as long as there are no winds. Hence this air, because it is humid, and the adjacent surface of the earth lose much heat during the

FIG. 61.

Radiation fog, Loudoun Valley, Va. (A. J. Weed, photo.)

night by radiation to the clear sky. In many cases they cool in the end to a temperature below the dew-point, and thus induce a greater or less volume condensation on the always-present dust motes that results in a correspondingly dense fog (Fig. 61). Such fog, however, is not likely to occur during cloudy nights, because the air seldom then cools sufficiently, nor during high winds, since they dissipate the humidity and also through turbulence prevent the formation of excessively cold aerial lakes.

The distinctive factor in the formation of this type of fog is the free radiation of the ground and the lower air by which the latter is sufficiently cooled to induce condensation. Hence fogs formed in this manner are properly termed "radiation fogs," sometimes also called "land fogs" and "summer fogs."

Advection Fog.—Whenever warm, humid air drifts over a cold surface its temperature is reduced throughout the lower turbulent layers by conduction to that surface and by mixture with remaining portions of the previous cold air and a correspondingly dense fog produced. Hence fog often occurs, during winter, in the front portion of a weak cyclone; also whenever air drifts from warm water to cold—from the Gulf Stream, for instance, to the Labrador Current; and wherever gentle ocean winds blow over snow-covered land—circumstances that justify the terms "winter fog" and "sea fog" (drifting on shore in places, and even some distance inland, Fig. 62). Similarly, a cold wind drifting or spreading under and through a body of warm, humid air also produces a fog, though usually a comparatively light one. This explains the fog that frequently forms, during winter, along the front of a "high," and the thin fog that occasionally is seen over lakes on frosty autumn mornings, when the water appears to be steaming—actually evaporating into air already saturated and thus inducing condensation. It also explains the frequent occurrence of "frost smoke" on polar seas.

If the wind is strong the turbulence extends through a comparatively deep layer. Hence in the case of warm air drifting over a cold surface if the movement is rapid the total duration of contact between any portion of the air and that surface is likely to be so brief that but little cooling can take place and no fog be formed. Similarly, it usually also happens that fog does not form when the cold wind blowing over a warm, humid region is even moderately strong. Here the turbulence mixes the ex-

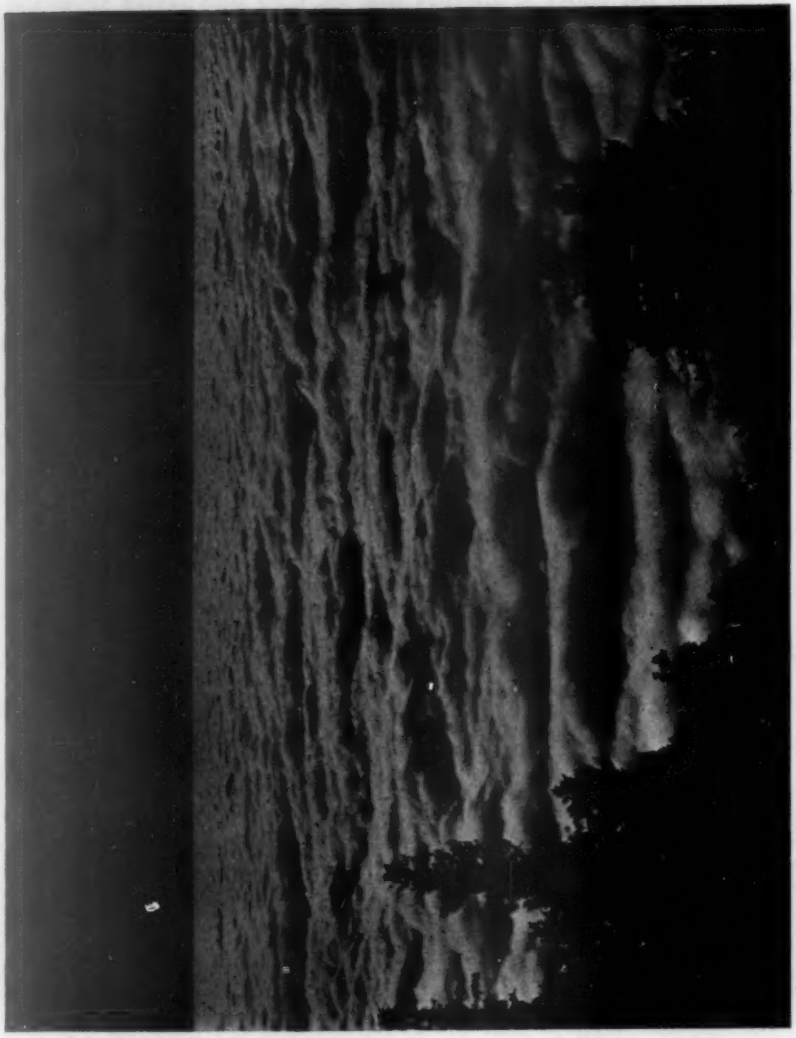

FIG. 62.

Advection fog, seen from Mount Willson, Cal. (F. Ellerman, photo.)

cessive humidity near the surface through so large a volume that saturation commonly is not produced, nor, therefore, any trace of fog.

From the above it appears that all fogs that result from the drifting of warm, humid air over cold surfaces, as also those that are produced by the flow of cold air over warm, humid regions, are but effects of temperature changes induced by the horizontal transportation of air; hence the proposed general name, "advection fog." The term advection is preferred to convection because the latter is practically restricted, in meteorological usage, to a change of level, whereas in the case under consideration only horizontal movements are concerned. The contradistinction, therefore, between "advection fog" and "convection cloud" is obvious, and, presumably, worth while.

CLOUDS.

The cooling of the atmosphere by which cloud condensation is induced is most frequently, perhaps, produced by vertical convection, either thermal or forced; often, presumably, by the mixing of winds of different temperatures; occasionally by pressure changes, elevation remaining the same; occasionally, also, by radiation; and rarely, in the case of very thin clouds, by diffusion and conduction.

Radiation, though productive of many fogs, is excluded from the list of principal cloud-forming processes for the reason that, as explained elsewhere, any mass of free air that cools in position, as it must whenever its radiation exceeds its absorption, immediately gains in density and falls to a lower level where, when equilibrium is reached, it actually is *warmer* than it was before the cooling began, and its relative humidity therefore lower. Hence it seems that radiation could produce clouds only when equally active, or nearly so, over an extensive layer of practically saturated air. If radiation is unequally distributed it tends to evaporate clouds rather than produce them.

Classification.—It is not practical, however desirable, to classify clouds according to their causes, as in the case of fogs, for it often happens that the exact cause is not obvious. Hence other bases of classification have been adopted, especially form or appearance, activity, and position. Most, but not all, clouds belong to one or other of the four distinct types, *cirrus, stratus,*

FIG. 63.

Cirrus. (P. Ellerman, photo.)

FIG. 64.

Cirrus. (P. Ellerman, photo.)

cumulus, nimbus, including their alto, fracto, and combination forms; alto-stratus, alto-cumulus; fracto-stratus, fracto-cumulus, fracto-nimbus; cirro-stratus, cirro-cumulus, strato-cumulus, cumulo-nimbus.

Cirrus (Ci.).—The name cirrus, literally a curl or ringlet, has been given to those fibrous white clouds that resemble great wisps of hair (mares' tails), giant curling plumes (feather clouds), tangled skeins, and various other things (Figs. 63 and 64). These are the highest, often 10 to 12 kilometres above the earth in middle latitudes and still higher in tropical regions, the most tenuous, and among the most familiar of all clouds.

Since cirri usually run far ahead of the rainy portions of cyclonic areas, and grow denser as the storm approaches, it is obvious that they frequently result from cyclonic convections that extend nearly or quite to the stratosphere, where, and for some distance below which, the rising air is carried forward much faster than the storm centre. But they also are fairly common in the midst of "highs," due, presumably, to a mechanical or bodily lifting of the upper air of these regions, or overrunning of air in the general circulation, and, consequently, dynamical cooling not only of the stratosphere, as abundantly shown by the records of sounding balloons, but also of the topmost portion of the troposphere where cirri usually form.

It has been suggested that cirri often are caused by cooling in place by radiation, but, as already explained, this appears to be improbable for clouds so broken and discontinuous. On the contrary, however, it seems likely that through free radiation and cooling at night they often sink to lower levels, get *warmer,* and evaporate. Thermal and mechanical convection, therefore, the first prevailing in tropical regions, the second, presumably, in extratropical, appear to be the only abundant causes of cirri.

The excessively low temperatures at which cirri are formed, generally −30° C. to −50° C., necessitate their being tenuous (at such temperatures there is but little water vapor to condense) and practically insure (exceptions have been reported[81]) that they shall consist of ice needles. Their fibrous and feathery structures may perhaps be explained as follows: Since diffusion is a very slow process, it follows that humidity is carried into the upper atmosphere mainly by vertical convection, and, as this

[81] Simpson, *Qr. Jr. Roy. Meteorol. Soc.,* **38** (1912), p. 291.

FIG. 63.

Cirro-stratus, and advection fog, seen from Mount Wilson, Cal. (F. Ellerman, photo.)

often occurs sporadically, it appears that through the increase of winds with elevation, the rising and generally humid air is likely to be drawn out into long threads and bands, and to float away in filaments at the convective limit, just as during the early hours of calm autumn mornings chimney smoke in mountain valleys often is drawn out into streaks and ribbons at or near the inversion level.

Any cloud, therefore, produced in this fibrously humid air obviously itself must have the same general structure—a common structure of cirrus clouds. Through local convection, however, and abrupt changes in velocity at the level of these clouds the air currents to which they are due presumably often are deflected into curves of changing radii. Hence, perhaps, the curved or plumed cirrus.

Cirro-stratus (Ci.-St.).—When cirrus clouds thicken, as they usually do on the approach of a cyclonic storm, they gradually merge into a broad cloud layer, having the appearance of a more or less continuous white veil of uneven and often fibrous texture (Fig. 65), to which the name cirro-stratus has been given. Its altitude is nearly that of the cirrus, of which indeed it is only a dense and extensive form, though its under surface is not so high. Like its forerunner, the thinner cirrus, it also consists of ice crystals, as is evident from the various types of halos it forms about the sun and moon.

The origin of these clouds is substantially the same as that of the cirrus; that is, convection, which in turn may be caused by general expansion of the air below or by convergence of winds, such as occurs in the cyclone. Frequently, as explained above, the cirro-stratus is only the higher and swifter portion of the cyclonic cloud system, the result of forced convection to great altitudes.

Cirro-cumulus (Ci.-Cu.).—Cirro-cumuli are small, fleecy cumulus clouds, generally 6 to 7 kilometres above the surface; that is, in the lower cirrus region. They usually occur in large numbers, producing an effect sometimes described as "curdled sky"; frequently, also, in groups and rows that remind one of the patterns (not the scales) on the backs of mackerel. Hence the expression "mackerel-back sky," commonly abbreviated to "mackerel sky" (Fig. 66).

Their origin obviously is due chiefly to a single cause—local

FIG. 66. Cirro-cumuli. (F. Ellerman, photo.)

FIG. 67.

Alto-stratus, and advection fog, seen from Mount Wilson, Cal. (F. Ellerman, photo.)

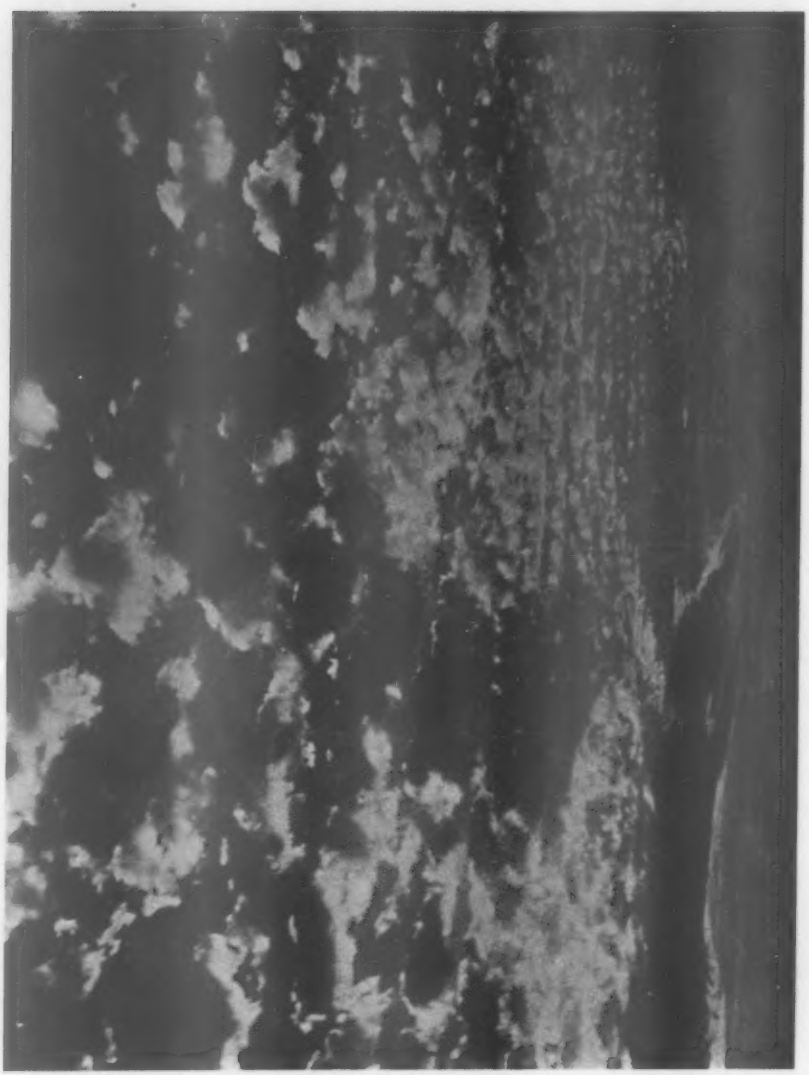

FIG. 68.

Alto-cumulus. (A. J. Weed, photo.)

vertical convection, induced by unequal local heating. To each convective rise of the air there evidently must be an equivalent descent, and if the heating maxima are numerous the minima between must also be numerous, thus producing many rising currents, each with its small cumulus, surrounded by descending air and relatively clear sky.

Alto-stratus (A.-St.).—The alto-stratus is a thick, grayish cloud veil (Fig. 67), at times compact and fibrous in structure, and again thinner, like a heavy cirro-stratus, through which the sun or moon may dimly be seen. Its average elevation is about 4 kilometres. It may result from the forward running of air forced up by the convergence of winds in the storm area of a cyclone, from the flow of warmer over colder air, or by mere radiational cooling in place, of a layer of relatively humid air—humid from the evaporation of alto-cumuli, perhaps.

Alto-cumulus (A. Cu).—The name alto-cumulus has been given to those detached, fleecy clouds, with shaded portions (Fig. 68), often occurring in closely packed goups and rows, that resemble enlarged cirro-cumuli. Their average altitude is approximately that of the alto-stratus—that is, 4 kilometres—and they presumably are formed by local convection, especially during fair, calm summer weather, when the relative humidity is low.

Strato-cumulus (St.-Cu).—Strato-cumuli are large rolls of dark cloud more or less connected with thinner clouds which together cover nearly or quite the entire sky (Fig. 69). Their bases are flat and at about the same height, generally 1.5 to 2 kilometres. They are formed by vertical convection, as is obvious from their rounded tops and flat bases at approximately the same level—the common saturation level.

Nimbus (Nb.).—The nimbus is any thick, extensive layer of formless cloud from which rain or snow is falling. The average altitude of its under-surface is of the order of 1 kilometre. It is produced chiefly by some type of forced convection: the converging of wind currents as occurs especially in front of cyclonic centres, the upward deflection of winds by either land or cold atmospheric barriers, and the under-running of warmer by colder air. In part, however, the cooling and consequent condensation often is owing to the mixing of cold air with

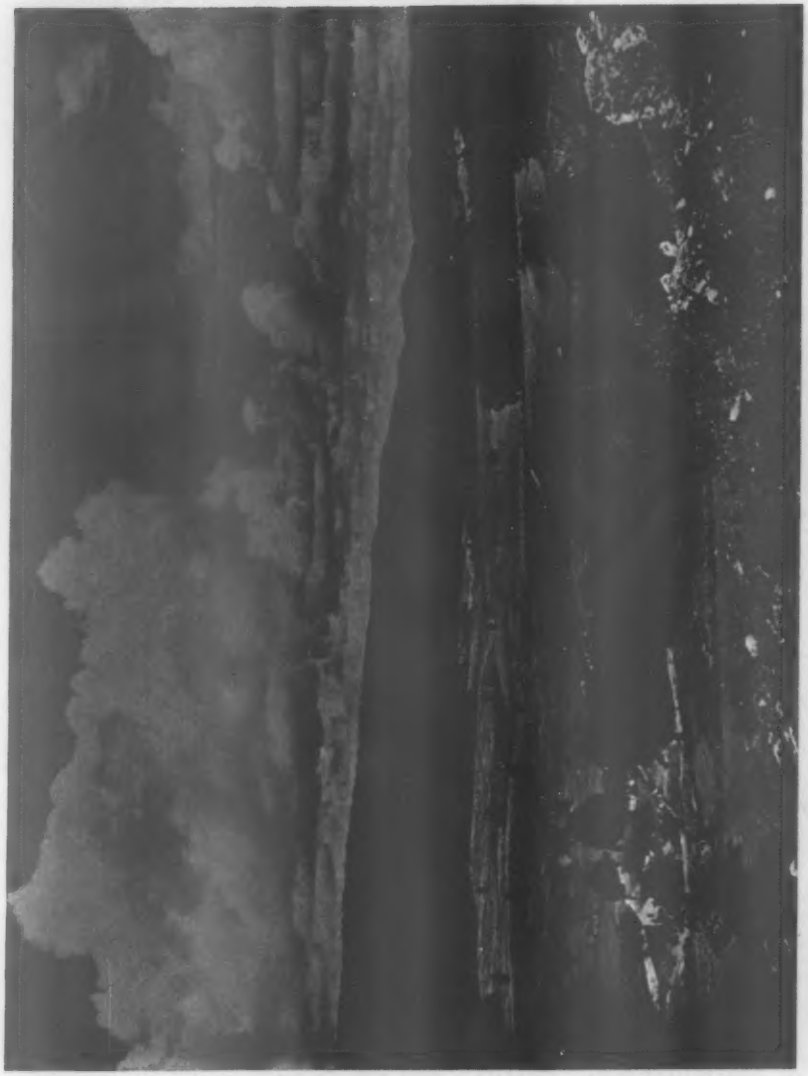

FIG. 69.

Strato-cumulus, or roll cumulus, near Gap Mills, W. Va. (L. W. Humphreys, photo.)

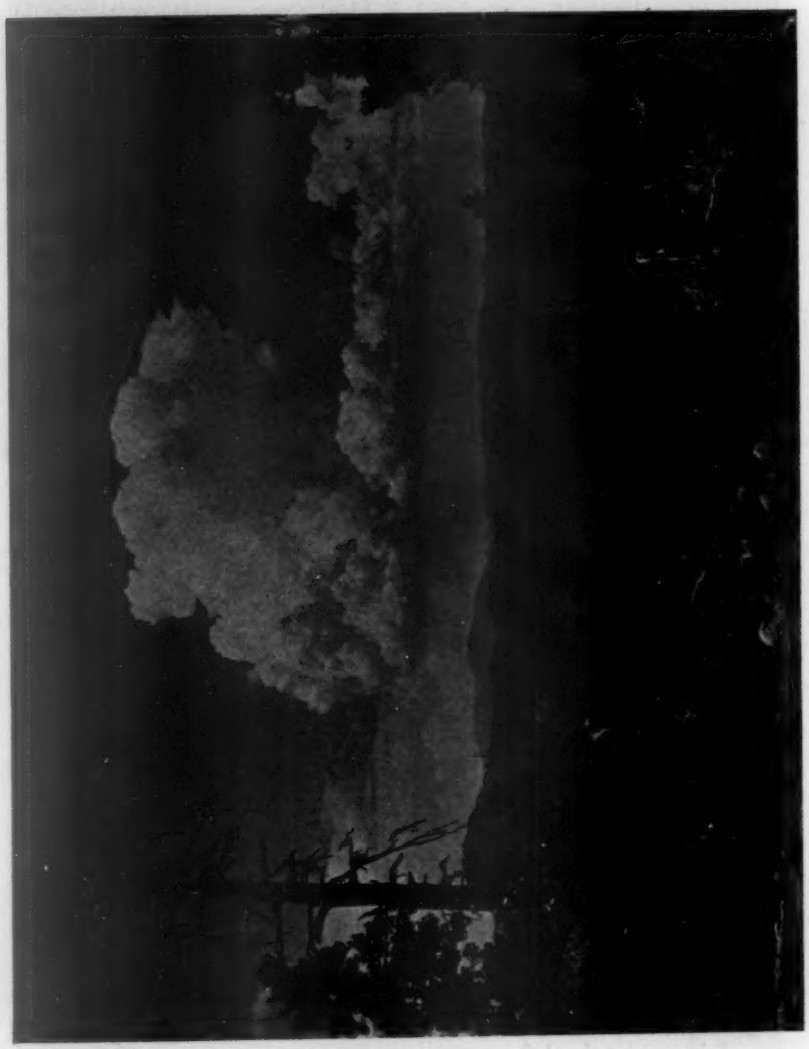

FIG. 70.

Cumulus, seen near Mount Willson, Cal. (F. Ellerman, photo.)

warm, and to the transfer of warm air to a colder region, where it is cooled by contact, by mixing with cooler air, and by excess of radiation loss over radiation gain.

Fracto-nimbus (Fr.-Nb.).—The fracto-nimbus, popularly known as scud, is that low, detached cloud fragment, too thin and fog-like to produce rain, that occasionally is seen drifting rapidly beneath a heavy nimbus at an average elevation of probably not more than 100 to 300 metres. It seems to form only when there is considerable wind, and appears often to be caused by forced convection over cliffs or other obstacles.

Cumulus (Cu.).—The cumulus (Fig. 70), often called "woolpack," is a dense, detached cloud with a rapidly changing cauliflower head and flat base at the saturation level of rising air. Its illuminated portions are snow white, while the shaded parts are unusually dark. Its border is sharply defined and, when near the sun, very bright. The average altitude of the base is about 1.5 kilometres, and of the top rather more than 2 kilometres.

Cumuli are produced entirely by vertical convection induced by temperature differences. Hence they are always frequent in tropical regions, and also over continents at higher latitudes during summer. For the same reason, they occur over land most numerously of afternoons, and at sea late in the night. At times rather low cumuli form a sort of coastal fringe along the locus of upward convection—that is, a short way out over the sea at night, and a few miles inland during the day—that might, perhaps, be called coast cumuli—attendants of the land breeze and the sea breeze, respectively. They often occur over reefs and islands (Fig. 71), whose presence frequently is thus revealed while they themselves are still below the horizon. Occasionally they even parallel a large river on either side where there is rising air over the hills and bottoms and sinking over the cooler water. Further, since vertical convection depends only on the establishment of a proper vertical temperature gradient, it follows that cumuli may also form at high latitudes over the warmer portions of the ocean, or, indeed, wherever there is a sufficient temperature contrast between the surface and overlying air to induce strong upward currents.

Fracto-cumulus (Fr.-Cu.).—During the initial stages, especially, of their development cumuli often are small, and appear

FIG. 71.

Cumulus over island—Krakatao. (E. E. Barnard, photo.)

FIG. 72.

Fracto-cumulus, in Monroe Co., W. Va., Peters Mountain to left. (L. W. Humphreys, photo.)

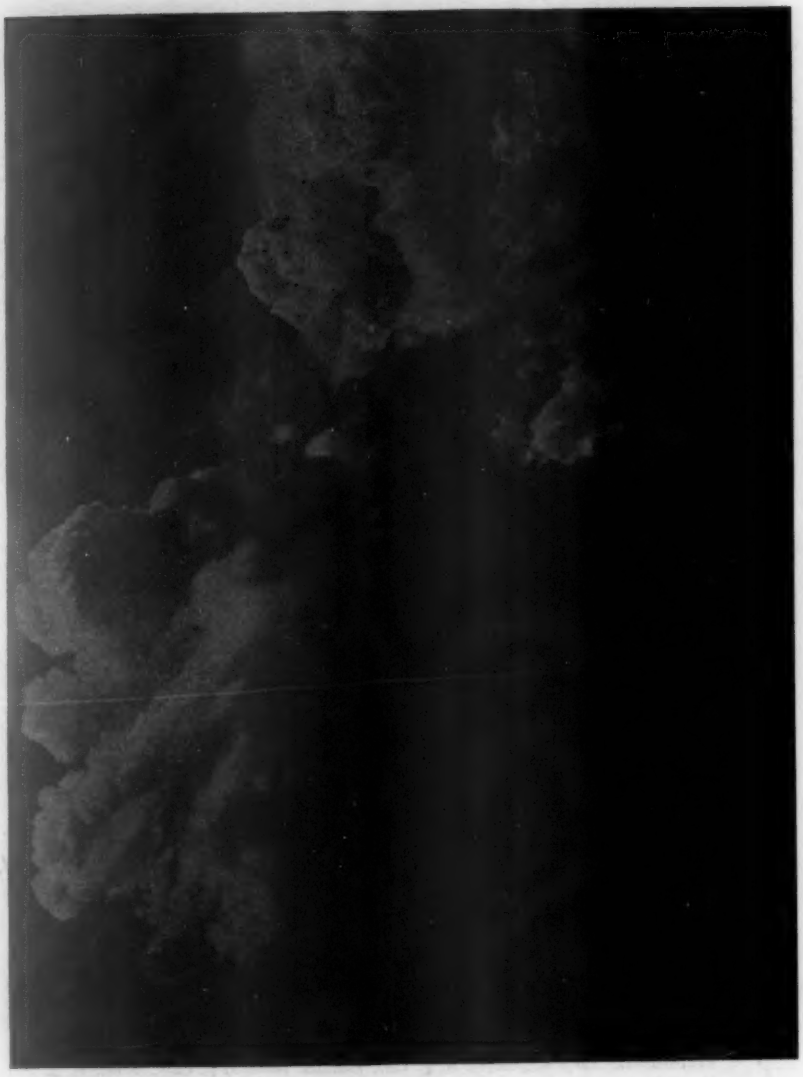

FIG. 73.

Cumulo-nimbus, over Loudoun Valley, Va. (A. J. Weed, photo.)

tattered and torn like detached and dissolving masses of fog (Fig. 72). While in this condition such clouds are often called fracto-cumuli.

Cumulo-nimbus (Cu.-Nb.).—The cumulo-nimbus (Fig. 73), a necessary accompaniment of every thunder-storm, is, as its name implies, a cumulus cloud from which rain is falling. It is very turbulent and much the deepest of all clouds, being anywhere from 1 to 4 or even 5 kilometres thick. Its times and places of occurrence and mode of formation are all the same as those of the cumulus.

Stratus (St.).—The stratus is a low, fog-like cloud of wide extent, often merging into a nimbus and again clearing away like lifted fog. Its average altitude is between 0.5 and 1 kilometre. It seems often to result from forced convection due to the underrunning of cold air, and also, perhaps, to the mixing of humid layers of different temperatures. In some cases, that of the "velo" cloud, for instance, in southern California, it is only sea fog drifting over relatively warm land.

SPECIAL CLOUD FORMS.

Although it might seem that the above cloud types, including their numerous gradations and transitions, are exhaustive, there nevertheless are several occasional forms sufficiently distinct to justify individual names and special descriptions.

Billow Cloud.—Billow clouds (Figs. 74 and 75), also called windrow clouds and wave clouds, occur in series of approximately regularly spaced bands, generally with intervening strips of clear sky. They usually form in the lower cirrus region—that is, at elevations of 6 to 8 kilometres—but may occur at any level from the surface—fogs are occasionally billowed—up to that of the highest cirrus. They are caused by the flow of one air stratum over another of different temperature and density and usually of different humidity.

It has been shown [82] that when two strata of air of different densities or vapor content flow over each other billows of great wave-length and often of large amplitude are generated in the

[82] Helmholtz, *Sitz. d. Akad. d. Wiss.*, Berlin, 1888, i, p. 646; 1889, ii, p. 761. W. Wien, *Sitz. d. Akad. d. Wiss.*, Berlin, 1894, ii, p. 509; 1895, i, p. 361. A. Wegener, *Beiträge Phys. d. fr. Atmos.*, 2 (1906), p. 55; 4 (1911), p. 23.

FIG. 74.—Billow cloud. (A. J. Henry, photo.)

FIG. 75.

Billow clouds, regular and irregular, over Washington, D. C. (A. J. Henry, photo.)

same manner that winds produce ocean billows. As the series of waves progress the atmosphere involved obviously rises and falls, and therefore is subjected to alternate dynamical heating and cooling, with the maxima and minima temperatures corresponding to the troughs and crests respectively. Hence when the under layer is wholly or nearly saturated the wave crests are cloudy and the troughs clear. If, however, the humidity is not high, it is obvious that wind billows may exist without the incidental clouds.

It is interesting to note that, although the billow cloud appears to consist continuously of the same mass, it nevertheless is rapidly evaporating on the rear or descending portion of the wave and as speedily forming on the front or ascending portion.

Lenticular Cloud.—The lenticular cloud (Figs. 76 and 77) is formed by the upward deflection of the wind over mountain peaks and, perhaps, rising air currents. In some cases, doubtless, the cooling is accentuated by the low temperature of the peak itself. In either case the cloud particles are rapidly evaporated as they are carried away, and the thickness of the whole mass reduced to zero at no great distance.

Crest Cloud.—The crest cloud is formed by the upward deflection of the wind by a long mountain ridge. It usually covers the higher slopes as well as the top, and, though called cloud by people in the valleys below, is likely to be designated fog by any one actually in it. Occasionally condensation occurs only along the upper reaches of the deflected winds, in which case the cloud belt is above and to the leeward of the mountain ridge.

In either case the individual droplets are quickly evaporated and the cloud form preserved only through continuous condensation from renewed air. It is permanent in the same sense that a cataract is permanent through the continuous supply of water by the stream above.

Banner Cloud.—The banner cloud (Fig. 78), as its name implies, resembles a great white flag floating from a high mountain peak. In strong winds the pressure to the immediate leeward of such a peak is more or less reduced, and the resulting low temperature, intensified, perhaps, by the mountain surface,

FIG. 76.

Lenticular cloud, over Mount Rainier. (O. P. Anderson, photo.)

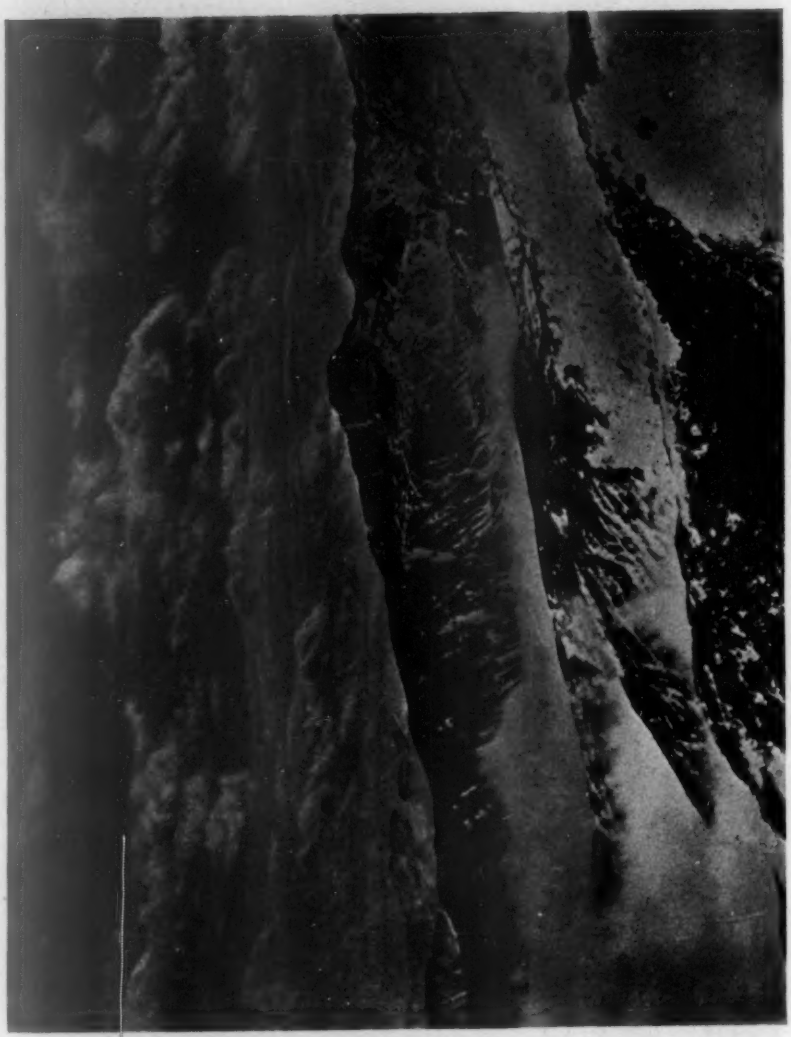

FIG. 77.

Lenticular clouds and fracto-cumuli over Rocky Mountains, nᵉ Corona, Colo.

FIG. 78.

Banner cloud, Mount Assiniboine, near Banff, Canada. (C. D. Walcott, photo.)

FIG. 79.

Scarf cloud. (W. A. Bentley, photo.)

appears to be the cause of this singular cloud that, though continuously evaporating, as constantly re-forms in the turbulent wake.

Scarf Cloud.—It occasionally happens that as a cumulus rises rapidly and to great heights a thin, cirrus-like cloud, convex upward, forms above the cumulus head and, at first, entirely detached from it. As the cumulus continues to rise the flossy cloud becomes more extensive and rests on the thunder head or heads. A little later it mantles the shoulders, the heads being free (Fig. 79), and may even drape the sides of the cumulus. In all stages it resembles a great silken scarf, hence the above-suggested name. It often is called false cirrus, but that name is now and better applied to a different formation. It has also been called cap cloud, but this is confusing, because the same term has long been applied loosely to any cloud that hovers above, or, especially, rests upon a mountain peak, and, besides, the cap analogy applies to only the early stages.

It is caused by the elevation and consequent expansion and cooling of the air immediately and to some distance above the rising mass of the cumulus. Generally this expansion of the superincumbent atmosphere produces no visible effect, but occasionally there exists a thin stratum of nearly saturated air in which an alto-stratus might form, or, indeed, later does form, and when this is lifted by the rising cumulus it immediately develops a local cirrus-like cloud. But if the saturated layer is thin, as it often is, the cumulus head may easily rise quite above it into dryer air, leaving the filmy cloud at practically its original level, the level of the humid stratum.

False Cirrus.—The name "false cirrus" formerly was applied indifferently to the scarf cloud, just described, and to those gray locks, to speak figuratively, combed out from old thunder heads by the upper winds. At present, however, the term usually is restricted to the latter phenomenon.

Although the lower atmosphere, up to at least 3 or 4 kilometres, generally is comparatively calm whenever cumuli are most conspicuous, it nevertheless occasionally happens that the highest thunder heads reach into a stratum of much greater velocity in which, therefore, the topmost portions of the cloud

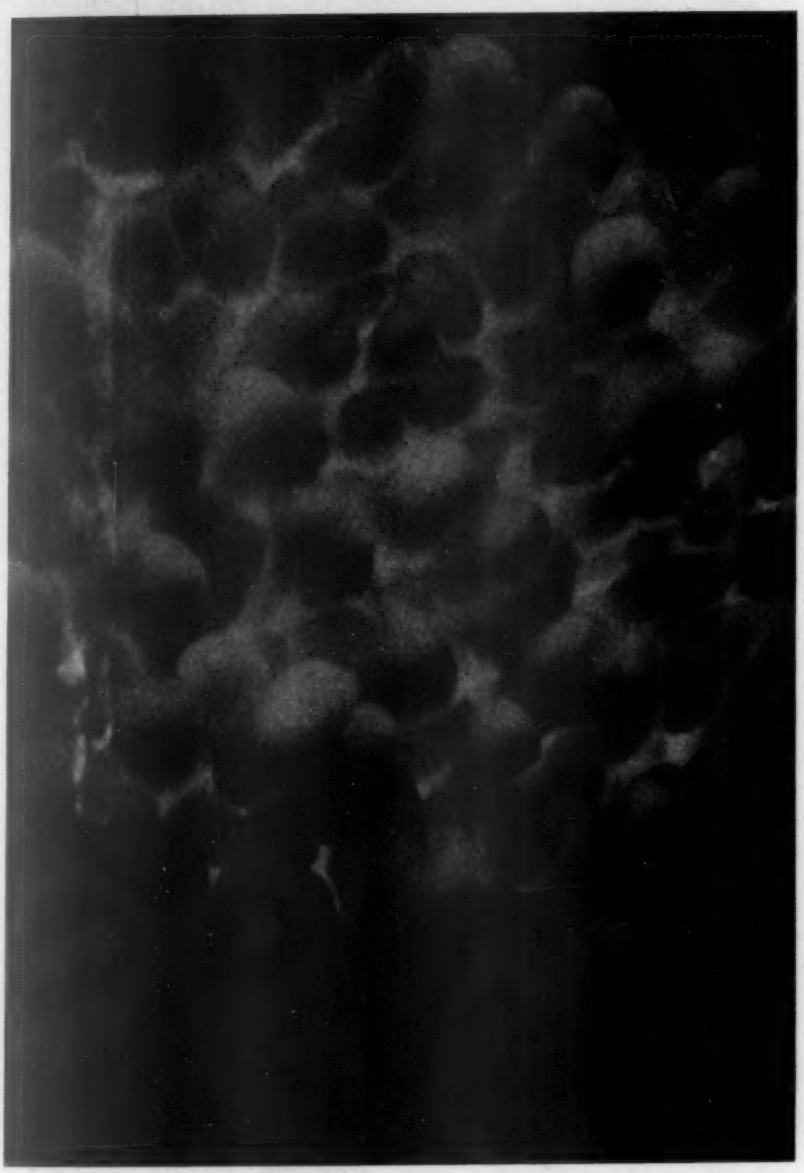

FIG. 80.

Mammato-cumulus. (L. C. Twyford, photo.)

FIG. 81.

Tornado cloud, Antler, N. Dak. (W. H. Wegner, photo.)

are drawn out into wispy bands and fibres of snow crystals—a truly cirrus cloud whose peculiar origin is, perhaps, its only claim to the special name "false cirrus."

Mammato-cumulus.—The mammato-cumulus, sometimes called pocky-cloud, festoon-cloud, "rain balls," sack-cloud, or other similar name, is essentially a reversed cumulus (Fig. 80). It generally occurs in an alto-stratus or cumulo-stratus cloud, and seldom except in connection with a severe thunder-storm.

As is well known, ice in the form of hail and snow often occurs in the upper portions of large cumuli. If, now, this snow, say, is drifted out just above a stratus cloud, it is obvious that the cooled layer will descend at many different places, and that at each such place there will be produced a sag or pendulous bulge in the cloud base and, of course, a lift or rise wherever the counter-current obtains, thus producing the festooned appearance characteristic of this rather unusual cloud.

Tornado or Funnel Cloud.—The tornado cloud (Fig. 81) is only a funnel-shaped extension of, generally, if not quite always, a cumulo-nimbus. It is produced by the expansional cooling incident to the rapid rotation of the atmosphere in which it appears.

CLOUD HEIGHTS.

Relation to Humidity.—The heights of clouds have been measured by several obvious methods of triangulation, and from the data thus obtained it appears, as one might infer *a priori,* that whatever condition tends to increase the relative humidity tends also to lower the cloud levels, since the greater this humidity the less the amount of convectional cooling essential to condensation. Hence, in general, each type of cloud is lower in winter than summer, lower over humid than over desert regions, lower over oceans than continents, and lower with increase of latitude.

The table on page 644, copied from Hann's "Lehrbuch der Meteorologie," gives the average summer and winter heights of clouds at places of widely different latitudes.

Levels of Maximum Cloudiness.—When the frequency of clouds is tabulated with reference to elevation, maxima and minima are found with the layers to which they obtain growing thicker with decrease of latitude. This phenomenon, as a whole,

is interesting, but it will be necessary, in discussing it, to consider the different levels separately, since each has its own explanation.

Fog Level.—As already explained, fogs, whether caused by radiation or advection, are surface phenomena, seldom more than 100 to 200 metres thick. Hence the surface of the earth, because of the fogs that form upon it, is itself a level of maximum condensation or maximum "cloudiness."

Cumulus Level (a), *Foul Weather Type.*—Since the cumulus and the cyclone nimbus both are due to vertical convection—

Average Cloud Heights in Kilometres.

Station	Ci.	Ci.-st.	Ci.-Cu.	A.-St	A.-Cu.	St.-Cu.	Nb.	Cu.-Nb. top	Cu. Top	Cu. Base	Fr.-Cu.	St.
	1. SUMMER, CHIEFLY APRIL TO SEPTEMBER.											
Bossekop, 70° N.	8.32	6.61	5.35	4.65	3.42	1.34	0.98	3.96	2.16	1.32	....	0.66
Pavlovsk, 60° N.	8.81	8.09	4.60	....	3.05	1.85	....	4.68	2.41	1.64	2.15	0.84
Upsala, 60° N.	8.18	6.36	6.45	2.77	3.95	1.77	1.20	3.97	2.00	1.45	1.83	....
Potsdam, 52½° N.	9.05	8.08	5.89	3.29	3.63	2.16	1.79	3.99	2.10	1.44	1.71	0.68
Trappes, 49° N.	8.94	7.85	5.83	3.79	3.68	1.82	1.08	5.48	2.16	....	1.40	0.94
Toronto, 43½° N.	10.90	8.94	8.88	4.24	3.52	2.06	....	....	1.70		....	....
Blue Hill, 42° N.	9.52	10.10	6.67	6.25	3.76	1.16	1.19	9.03	2.90	1.78	....	0.51
Washington, 39° N.	10.36	10.62	8.83	5.77	5.03	2.87	1.93	4.96	(2.45)	1.18	....	0.84
Allahabad, 25½° N.	10.76	.....	11.28	....	4.50	....	0.84	....	1.76		....	....
Manila, 14½° N.	11.13	12.97	6.82	4.30	5.71	1.90	1.38	6.45	1.84		....	1.06
Batavia (year), 6° S.	11.49	10.59	6.30	....	5.40	....	....	....	1.74		....	0.70
	2. WINTER, CHIEFLY OCTOBER TO MARCH.											
Pavlovsk	8.74	7.09	5.98	....	3.17	1.50	....	....	1.60	1.12	....	1.00
Upsala	6.98	5.46	6.13	4.09	4.15	1.96	0.99	5.18	1.52	0.71	1.22	0.51
Potsdam	8.07	7.65	5.41	2.99	3.35	1.42	1.28	4.74	1.74	0.99	1.02	0.61
Trappes	8.51	5.85	5.63	3.82	4.27	1.61	1.05	3.85	2.37	....	1.43	....
Toronto	9.98	8.53	8.25	4.18	2.50	1.54	....	....	1.33		....	....
Blue Hill	8.61	8.89	6.16	4.57	3.66	1.60	0.65	....	1.62	1.54	....	0.61
Washington	9.51	9.53	7.41	4.80	3.82	2.40	1.80	3.73	2.28	1.20	....	1.13
Manila	10.63	11.64	6.42	3.90	4.64	2.32	1.49	3.14	1.82		....	....

the first thermal, the second forced—it is obvious that the base of each occurs approximately at the saturation level; that is, the level at which a mass of air rising from the surface will have cooled to its dew-point. Clearly, too, clouds cannot form at a lower level, the air there being unsaturated,—even if drifted in they would evaporate. Further, ordinary thermal convection usually does not extend to much higher altitudes, because the cooling of the rising mass through expansion and evaporation (the outer portions, at least, of the cloud evaporate) quickly brings it to or below the temperature of the surrounding air at the same level, except in the case of the largest cumuli, in

which the amount of evaporation is very small in comparison to the total condensation. Hence foul weather cumuli and the lower cyclone clouds mark a second level of maximum cloudiness, commonly 1 to 2 kilometres above the surface.

Cumulus Level (b), *Fair Weather Type.*—During fair, calm, summer weather vertical convection is very strong, but, as the relative humidity is low, the resulting clouds are of the alto-cumulus type. Hence the alto-cumulus, 3.5 to 4 kilometres above the surface, marks a secondary or fair weather cumulus level of maximum cloudiness.

Cirro-stratus Level.—Since the different types of cirrus formed in the region of a cyclone (the cirro-stratus being, perhaps, the most frequent) are spread far in advance of the storm itself by the swift upper winds, it follows that they also mark a level of maximum cloud frequency.

Cirrus Level.—During fair weather thin cirri often occur, as already explained, at or near the top of the troposphere, due, probably, to that marked cooling of the upper atmosphere characteristic of "highs," and, as these are the highest of all clouds, it is obvious that they denote a final level of maximum cloudiness, one whose average elevation in middle latitudes is about 10 kilometres.

Regions of Minimum Cloudiness.—Between the levels of maximum cloudiness there obviously must be regions of minimum condensation. These are:

Scud Region.—Since one level of maximum cloud formation, including fog, is at the surface of the earth and the next at an elevation of approximately 1.5 kilometres, the average base height of the cumulus, it follows that the intervening region is one of minimum cloudiness, the absolute minimum being just above the highest fog. The name "scud region" might be appropriate to this space, since "scud" is, perhaps, the only cloud that occurs in it.

Intercumulus Region.—The intercumulus region of minimum condensation lies, as the name suggests, between the cumulus and alto-cumulus levels of maximum cloudiness. Its elevation is, roughly, 2.5 to 3.5 kilometres.

Alto-stratus Region.—As the alto-cumulus and the cirro-stratus mark adjacent levels of maximum cloudiness at the heights

of about 4 and 8 kilometres respectively, it follows, as above, that the region between, at the heights of 4.5 to 6 kilometres, especially the higher alto-stratus region, must be one of minimum cloudiness. And this it is, because (*a*) it is above the level of diurnal convection and therefore of most cumulus clouds; (*b*) the clouds of intermediate level formed in cyclonic areas are not blown forward so rapidly nor, therefore, over such wide areas as are the cirri; and (*c*) the atmosphere at this level in anticyclones is nearly always dry, apparently dynamically warmed, and therefore non-cloud-forming.

Intercirrus Region.—Since the cirrus region furnishes two adjacent levels of maximum cloudiness, a foul (cyclonic) and a fair weather type, whose elevations are about 8 and 10 kilometres respectively, it follows that an intercirrus region of minimum cloudiness must lie between them at any elevation of, say, 8.5 to 9.5 kilometres.

Isothermal Region.—Obviously water vapor is not carried in any considerable amount beyond the limit of appreciable vertical convection. Hence, there being but little water vapor present, clouds cannot form in the stratosphere; that is, beyond an elevation of about 11 kilometres in middle latitudes.

There are, then, five principal levels of maximum cloudiness:

1. Fog level, surface of the earth or water.
2. Cumulus level, height above surface about 1.5 kilometres.
3. Alto-cumulus level, height above surface about 4 kilometres.
4. Cirro-stratus level, height above surface about 8 kilometres.
5. Cirrus level, height above surface about 10 kilometres.

There also are five regions of minimum condensation:

1. Scud region, 100 to 300 metres elevation.
2. Intercumulus region, 2.5 to 3.5 kilometres elevation, roughly.
3. Alto-stratus region, 4.5 to 6 kilometres elevation, roughly.
4. Intercirrus region, 8.5 to 9.5 kilometres elevation, roughly.
5. Isothermal region, beyond 11 kilometres elevation.

Cloud Depth or Thickness.—It is known that the thickness of clouds varies from the 8 or 10 kilometres of the most towering cumulus, usually associated with a violent hail-storm, down to that of a vanishingly thin cirrus. Systematic measurements of cloud thickness, however, have not been numerous. The best,

perhaps, were made at Potsdam and are given in the following table copied from Hann's "Lehrbuch der Meteorologie":

Cloud Thickness.

Cloud		A.-St.	A.-Cu.	St.-Cu.	Nb.	Cu.-Nb.	Cu.	Pr.-Cu.
Depth in metres	Average....	510	194	353	(590)	2070	669	214
	Maximum..	1310	370	1265	1240	>4600	2230	430
	Minimum..	105	50	50	160	340	90	70
Number of observations.....		6	18	18	16	21	22	26

Cloud Velocities.—The velocity of a cloud is the velocity of the air in which it floats, except in the case of a stationary type—crest cloud, banner cloud, et cetera—or a billow cloud. With these exceptions, it therefore is approximately the gradient velocity at the cloud level, which varies with altitude, latitude, temperature, and pressure distribution.

Average values, observed at certain places, are given in the following table, also copied from Hann's "Lehrbuch der Meteorologie":

Average Wind Velocity in Metres per Second.

	Ci.	Ci.-St.	Ci.-Cu.	A.-St.	A.-Cu.	St.-Cu.	Nb.	Cu.-Nb. Top	Cu. Top	Cu. Base	Pr.-Cu.	St.
	1. SUMMER, CHIEFLY APRIL TO SEPTEMBER.											
Bossekop, 70° N....	18	18	11	13	11	5	6	..	7	7	..	7
Upsala, 60° N.....	20	(39)	17	5	12	7	7	..	7	6	8	..
Potsdam, 52½° N...	22	24	13	11	10	9	11	9	8	6	7	7
Trappes, 49° N.....	23	23	23	15	13	9	10	14	10	9	8	10
Blue Hill, 42° N....	30	30	18	25	13	10	14	22	13	9	..	6
Washington, 39° N..	30	27	23	18	16	10	8	15	7	..	..	6
Manila, 14½° N....	13	16	3	..	11	4	..	..	..	..	..	..
Batavia (year), 6° S.	12	19	3	..	6	6	..	..	4	..	..	1
	2. WINTER, CHIEFLY OCTOBER TO MARCH.											
Upsala.....	23	13	18	..	13	12	6	18	12	..	12	..
Potsdam.....	28	20	24	16	16	12	13	28	10	(14)	12	10
Trappes.....	23	19	27	18	14	11	16	..	12	12	11	10
Blue Hill.....	37	41	36	25	24	13	13	..	..	15	..	10
Washington.....	35	30	33	21	21	15	12	21	11	..	..	10
Manila	13	16	3	19	4	8	6	..	..	..	..	..

(To be continued).

Nitrification of the Soil by Electricity. R. D. McCREERY. (Communicated by the Author, Chicago, April 16, 1918.)—In this latitude it is estimated that 10 to 11 pounds of nitrogen per acre per year is precipitated to the earth by the natural electric disturb-

ances in the atmosphere in the form of nitric acid. In the Tropics, where thunder-storms are more frequent and static conditions augmented, a larger amount is precipitated, and vegetation is therefore, as we know, more abundant. If we therefore discharge electricity through the soil and through the air and moisture in the soil, we not only stimulate the bacteria of life to greater activity known to occur after natural electrical discharges, but give them their principal plant food by producing nitric acid and nitrogen. The writer believes that the most rational and practical way to apply electricity to plant life is through the surface of the soil to the roots of the plant, because the two necessities, moisture and air, are always present and because the bacteria of life are located in the plant roots, and, further, because the electrically produced nitric acid and nitrogen are deposited where needed.

In coöperation with the Engineering Department of the Western Electric Company, Chicago, Ill., the writer has in the past year successfully tested a newly patented process embodying this principle. High-frequency current is literally driven in a spray through the surface of the soil from special distributing electrodes embedded in the earth (about 6 inches deep), arranged parallel to each other on two opposite sides of the field along the fence lines, out of the way of cultivation. The seeds, before planting, are coated with a finely divided, non-deteriorating metal, with the object of creating lines of low resistance and a condition analogous to the coherer of a wireless set. Tests were made on 11 acres of corn and a few rows of sugar beets at Lombard, Ill. The increase in the corn production is estimated at 30 to 40 per cent., with an increase in the value of the crop estimated at $25 to $35 per acre. It is claimed that the cost per acre for current and metallically coating the seed is less than 50 cents per acre, and the net cost of the apparatus installed less than $200.

Duo-negatives for Excessive Contrast. E. FELLOES. (*Camera Craft*, vol. 25, No. 2, p. 63, February, 1918.)—In photographing subjects with intense contrasts, the difficulty of securing the requisite amount of detail in the shadows without getting over-density in the high lights is a common experience. The use of films makes it possible to overcome this difficulty by a simple expedient. Two negatives are made, one for high lights with a short exposure, and the other fully timed for the shadows. The parts desired in each negative are then coated with celluloid varnish and the remainder removed with the well-known red prussiate and hypo reducer. When these two negatives are superposed in register, their combined effect is that of a properly timed negative. The method, of course, requires some dexterity in the blocking-out process, and is restricted to films of negligible thickness.

MILITARY HIGHWAYS.*

BY

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In its broadest sense a military highway can be defined as any highway over which equipment, men, or supplies are transported in the conduct of military operations. It may be located to serve a base of supplies, to connect the base with the front line of action, or to distribute supplies behind the firing lines. It is a unit of the transportation system which may involve in its entirety systems of highways, waterways, railways, tramways, and air routes.

In the conduct of modern warfare we now know that the highway plays no small part, because, in addition to its use as an avenue for marching troops, supply wagon trains, cavalry, and artillery, it affords a means of rapid transport that is easily, quickly, and economically constructed to carry heavy units of artillery and accessories, and the moving of large numbers of troops quickly from one part of the field of action to another by motor vehicles, as so often required in the present war. The value of possessing a comprehensive system of military highways becomes at once very apparent when we hear that France was practically saved by her ever-ready system of roads and the great number of available motor busses, which quickly conveyed her troops to the point of attack. But in this connection we must not confuse the fact that the system as now completed at the French fighting front was not complete to start with; but it consists in considerable part of extensions to main arteries which were built years ago according to a program having the civil as well as the military needs as a basis of design.

This, in fact, is the only basis upon which any comprehensive system of highways can be designed, and any system not based upon the civil as well as the military problems involved is not

* Presented at the Stated Meeting of the Institute held Wednesday, December 19, 1917, by Mr. E. W. James, General Inspector, Office of Public Roads.

only uneconomical but unstrategic, because the present war has thoroughly demonstrated that the organization of all civil as well as military elements is absolutely essential to the rapid production of large supplies and their speedy delivery. In this latter the highways are great factors.

The French road system as it existed has not provided local fighting line roads except as the forces have taken up positions along the highways, and in the location of the military roads in France there is apparent no idea of providing roads to accommodate traffic necessary on a hypothetical battlefield. Manœuvring for strategic advantage in position has considered the existing roads as topographical features. The battlefields have in part been controlled by the roads, rather than the reverse. In the system as built important centres were systematically connected. Through truck roads, on exceedingly good locations, were provided, and the radial system actually existing developed as a result of these primary considerations. Main roads from Paris to all large centres in France furnish Paris with a radial system, and similarly for the lesser cities of France. The development of the local network existed to some degree in the French system in August, 1914, but many miles of local roads have been built behind the fighting lines, not only to replace destroyed roads but to serve local military purposes. Reports from Italy state that four thousand miles of such roads have been built. Our problem, then, is not to develop a local network over small areas, but to provide, first, a series of main arteries between the large centres. In considering this phase of location in a large way it is well to see what is writ large in our national territory. For instance, if we should undertake to develop highways for military or any other purpose on the same scale that France has, there would be 32,000 miles of national roads in the state of Texas, and four times that mileage of intercounty roads; there would be as many main roads in New York and Pennsylvania as there were in Germany, and as many in New England as in Old England, Scotland, and Wales. The development of such a system in detail would be unwarranted by our present economic requirements in times of peace.

Further, the local construction of so close a network of roads would not be warranted over any one area to the exclusion of others. The total battle line on the Western Front, although

extending from Switzerland to the Channel, is not so long as the distance from Washington to Boston. The overdevelopment of roads in such an area at the expense of a less development over a much larger area would obviously be a serious error. An enemy would simply go where the system did not exist and there attack.

To adapt the radial system of Germany or the old Roman system of Italy and France to the United States without modification or adjustment to American conditions and distances would be not only uneconomical but a military failure; because America has no one centre to build out from as a base to surrounding foreign countries and because the enemy would certainly not choose a port of landing supported by the best network of highways feeding it.

It appears plain, then, that the underlying principle of road location in a large way is to provide, first, the large open net of through roads over the entire area of boundary, choosing first those areas most open to attack.

Certain areas are obviously within this class; such as (*a*) the area about Long Island, comprising the New England states and New York; (*b*) the area about Chesapeake Bay, comprising much of New Jersey, Pennsylvania, Maryland, Delaware, Virginia, and North Carolina; (*c*) the Pacific Coast area of three states; (*d*) the Mexican border, comprising the southern part of Texas, New Mexico, and Arizona; (*e*) the Great Lakes area, comprising parts of the Lake states; and (*f*) the Gulf area, comprising parts of the southern Gulf and Atlantic states.

In addition to a large network of roads, connecting the centres of population in these areas, there should be through roads leading inland to important centres of manufacture and supply. The number of these necessarily depends on economic conditions. Roads should connect the Pittsburgh, Cincinnati, Detroit, Chicago, Birmingham, and other big industrial districts with the coasts. Such roads have already been found to provide a type of communication much needed, although they would appear on casual thought to be of little value, inasmuch as they parallel main rail lines with a lower and less useful form of travelled way or roadbed.

As the probable demands arising from war conditions on any particular part of the larger highway net cannot be foreseen,

for the very simple reason that the actions of an enemy cannot be foretold, we find that the immediate economic and engineering considerations under peace conditions are those that must control in the engineering location in detail of these roads. The selection of any system of highways depends upon the following factors:

(*a*) Population and its distribution, (*b*) location of sources of raw products, (*c*) shipping points for such products, (*d*) location of manufacturing centres, (*e*) the amount of traffic between such centres, (*f*) the character of such traffic. Upon consideration of such factors highways fall into two classes: (*a*) primary and (*b*) secondary. The former are commonly called through roads, and connect a series of centres of population or commerce. These conditions prevail in the military as well as the civil classification, and the selection must be governed accordingly. The primary system must be designed in accordance with the demands of traffic and act as main arteries for the secondary system. The secondary system should be selected as feeders and connections to the primary system. It has been calculated quite accurately that twenty per cent. of the highways in America carry eighty per cent. of the traffic. Military expediency might bring local roads into the class of primary highways, should any area become a theatre for military operations, and every effort should be made to consider this point in the design of the system. Still the main arteries, the primary system alone, must be relied on back of the lines to carry the bulk of the load up to the zone of action where the secondary and additional roads are improved or built as required.

The design for highway improvements under ordinary conditions is not beyond a reasonable determination after a careful study of the traffic by means of traffic census and knowledge of the country to be served. The density of traffic under peace conditions never can equal that flowing from the demands of war, and any attempt to meet the possible military demands on all roads would result in a breakdown of the highway policy when considered from no other than an economical standpoint. For example, the Bar-le-Duc-Verdun road in France, about 50 miles in length, was forced to carry, during the months of the attack on Verdun, a continuous line of five thousand motor trucks throughout the day and night. Traffic moved in four lines along the highway, the speed of the vehicles varying with the

line in which they travelled. Slow-moving horse-drawn vehicles moved along the shoulders, and the trucks moved at about a rate of twelve miles an hour, spaced fifty feet apart, with breaks of one hundred to two hundred feet now and then to allow for high-speed vehicles to shunt into line on passing the usual trains of trucks.

The construction of roads to carry such traffic is only advisable where it appears from the best military information that a similarly congested traffic might be likely to develop in certain very limited areas. For instance, as a part of the general network of roads already described certain sections from important railroad centres in the middle Connecticut Valley, the upper Hudson Valley, and the middle Susquehanna Valley might be constructed to take such traffic as the Bar-le-Duc-Verdun road carried to within easy striking distance of Boston, New York, and Philadelphia. But the mere statement of such a decision is open at once to the reply that to meet the possible needs practically any road in the system might become subject to the unusual conditions.

We are thrown back, then, in our detailed location and design very largely upon the same considerations as control highway construction in times of peace.

The military road should therefore be the most economical one, just as in the case of the selection under peace conditions; and, except in cases of emergency, the usual factors will apply. The most economical highway under all conditions is the one which results in the longest life for the amount of money invested and that serves its traffic with ease and safety. It is seen that the demands of traffic are the underlying basis of consideration for the improvement of any road and in turn govern the physical construction through the factors of location, character of improvement, type and width of surfacing, alignment, grade, etc. In general, a military road should be designed to carry traffic without delay or confusion, and with a minimum of effort.

Considerations of engineering location are controlled by the same details as for ordinary highway construction. A slight adjustment of some of our assumptions of design should be made. Grades should not exceed five per cent., except that an emergency maximum up to ten per cent. for not more than fifty yards may be allowed. Alignment should have no curves with radius less than two hundred feet, and a vista of not less than

three hundred feet. The road foundations and bridge structures should be designed and built to carry at least six thousand pounds forward and eight thousand pounds rearward on a wheel base of 10 × 5 feet. The paved surface should be twenty feet wide and the grade thirty feet wide.

It is seen at once that, with the exception of the last, such requirements are warranted economically in time of peace only on a coarse network of important intercity roads such as that already outlined.

On the large coastwise net and through routes to the interior developments could, of course, continue as traffic demands increased. States having funds could fill in the net with smaller meshes, and the same requirements of design should ultimately apply to these as apply to the ordinary strands of the net, although a lower standard of design might at first be adopted. In many of our states such development already exists.

Much has been said lately of materials and methods of construction. It appears, from the most reliable and first-hand sources of information, that water-bound macadam, telford, V-drains, and stone base are the most effective purely military types of construction. We know that such type is not economical in many localities under circumstances of a piping peace. For this reason the type selected for use in our suggested system may be in accordance with current economic rather than possible military demands. But it is to be remembered that a requirement of maintenance controls under actual fighting conditions. Repairs must be made easily, rapidly, and without in the least interrupting or diverting traffic. The traffic carried by the Bar-le-Duc-Verdun road was astounding in its wear and could not be halted. The question of restoration of road surface called for much ingenuity, and was a matter of extreme expediency. Just what our American higher types of pavement would have suffered is hard to determine, as none of them is found to any great extent in the European zones of activity. Many of them would doubtless stand heavy pounding for a longer time than the macadam, but when rupture came the invariable requirement of immediate repair would force resort to materials and methods capable of rapid and effective application.

The records furnished us so far indicate that water-bound or clay-bound macadam has been generally used by the French

and English immediately behind the Western Front. In the accounts, however, little differentiation has been made between the roads actually within the range of shell-fire, in what might be called the battle area, and those to the rear. It seems most likely that American practice can develop an improvement over the water-bound macadam patching in both areas, more especially on the main roads beyond range of shells. The advance that we have made in the last five years in the development of cold patch materials and their use indicates the great possibilities in this direction.

This method can be used on almost any type of wearing surface, from ordinary water-bound macadam to concrete or brick. So if we have any given system of roads constructed to meet the demands of normal traffic in times of peace, these roads may be repaired either with cold patches or water-bound patches if they ever come within the range of hostile artillery.

Roads built or rebuilt as the immediate accessories of an advance must be of materials that consolidate and furnish a travelled way in the least time. Such roads will probably be found in water-bound macadam or gravel. Likewise the repair of these roads, so long as they remain a part of the battle area, will have to continue in part of this type, or perhaps, under some conditions, of cold patch materials.

In this connection it is interesting to note that, when the War Department began the enormous task of building the National Army cantonments, a considerable mileage of camp roads and streets became necessary. The general opinion of those having the matter in charge was quite uniformly in favor of placing a gravel or macadam base at once wherever such materials were available. There were only a few exceptions to this plan in actual construction. The reason for this opinion was obviously that such types could be built most rapidly, and the same day a hundred feet of road was laid it could be used. Further, such construction would serve adequately as a foundation for any topping or surface treatment that might later be considered necessary. In fact, there has been considerable surface treatment, some bituminous macadam, in one or two cases bituminous concrete, and rather generally concrete platforms at warehouses constructed in the several cantonments. The company streets have generally been left as gravel or macadam.

These plans were arrived at independently of any information from the fighting front, as information was not then available. The decisions were reached solely upon a common-sense consideration of the highway problem.

The result of a departure from this general solution of the cantonment road problem is seen in detail in the work being done at Quantico, in Virginia. There it was decided to use concrete. At one time a daily rate of construction of five hundred linear feet of fifteen-foot road was reached by a single mixing plant. This is a rate of about three miles per month. But even this rate was not sufficient to enable completion of the work during the summer and fall. To continue operations into the winter it has become necessary to adopt expensive and unusual methods in order to insure the pavement against freezing and consequent serious damage. The blocks as laid are covered first by a framework of wooden slats; over this is spread a three-ply canvas tarpaulin. A layer of straw and stable refuse is spread on this, and the road remains thus covered about ten days to two weeks. It is necessary, also, to heat both the sand and large aggregate, and this is done by placing through the piles of materials metal cylinders in which fires are built. In addition, the water for gauging the concrete is heated before use, and thus the temperature of the entire mass is kept above the freezing-point until the block is poured and covered with the protecting canvas and straw mat. Of course, these precautions have materially reduced the rate of construction.

Under circumstances like these, which can occur in any latitude north of 33 degrees, and should be confidently expected anywhere north of 36 degrees, it is seen at once that the exigencies of rapid construction, immediate serviceability, and simplicity of method and materials throw us back upon the lower rather than the higher types of road surfacing.

Naturally these observations raise the question of costs. It has been stated in a reliable account that from ten to twelve thousand men have been used in one road organization on the British front in Flanders, that four thousand men were at one time on a single mile, and that stone has cost as much as $7.50 per cubic yard. The only statement pertinent is that cost is not considered. Much work is done by hand on the Western front, however, that by American methods might and probably would be done by machinery.

The question of shell holes is interesting, but the destruction from this cause is, according to the best information, much less in general than the layman supposes. Shells that bury themselves in loose earth before exploding burst almost at contact with a hard road surface and expend much of their force in the direction of least resistance. Consequently, shell holes on the roads are much shallower and smaller than in the fields. Moreover, it is costly business wasting ammunition in indiscriminate shelling of roads. Such destruction as occurs is usually the result of attempts to destroy motor trains or other transports passing over the roads, and is concentrated over a very limited length. Attempts to cut a road by shell fire are usually directed at points where aeroplane photographs indicate cuts or fills. The shelling aims to blow in the cut or blow out the fill. As a matter of fact, there appears to be little shelling of roads merely as such.

For these reasons the large bulk of repair work is the replacing of worn or scattered road metal. There appears to be nothing unusual in the methods used to make these replacements. A roller cannot commonly be used until the congestion of traffic is reduced so that it can be thrown on one-half of the road surface. Then the rollers are put on and the surface thoroughly repaired. Roads that have been gradually brought out of the battle zone by advancing forces are at the earliest moment practically rebuilt, being put into a condition as good as new, according to the reports at hand. If the same series of events occurred in the United States it appears probable that, with the persistence of heavy traffic even after the road has passed beyond shell fire, its reconstruction would have to be rapid and so conducted as to cause a minimum interference with traffic. For this reason it appears most probable that, regardless of original type, such reconstruction would quite generally be of gravel or macadam, at least until the fighting passed entirely out of the region tributary to the road.

We have no data that will lead to a choice of materials with respect to an effort to produce the effect of "camouflage." The French engineers have generally given up attempts to disguise a highway. The reason for this is rather obvious. The enemy locates these roads in the first instance from maps secured in time of peace. He corroborates his evidence by photographs taken from observation balloons or aeroplanes. The reflection of

light from the regular road surface produces a road in the picture regardless of the color of the surface. The road always appears in the photograph in plain contrast with the surrounding terrain, from which the reflection is irregular. The local attempts at camouflage are now confined to the distribution of branches or brush so as to cast irregular shadows across the surface.

In this connection a detail of importance appears to be the suppression of dust. Although the roads are not gratuitously and promiscuously shelled, they are watched, and if a cloud of rising dust indicates the passage of a support train or ambulance, that cloud at once becomes a target. The use of light oils or other familiar dust palliatives is of advantage. This also reduces the chance of accident from driving into a fog of dust.

The question of road control is interesting because of the unmistakable demands arising from a military use of the roads. But at the present time the Government has control over only those roads on military reservations, and none but the Secretary of War would have authority to designate other roads of military importance. With respect to the existing present needs the Secretary of War has written as follows:

" . . . to the request . . . that the War Department make known the needs of the military situation in respect to the construction of roads with moneys appropriated by the Federal Post Road Act of July 11, 1916, I have the honor to make the following recommendations:

"(1) Federal aid under the act above mentioned should, in general, be granted only for roads such as can be designated 'through roads'—that is, roads leading from one centre of population or commerce to another. Assistance in building branch roads for automobiles or tourists to visit points of scenic or historical interest does not appear warranted when there is still such a pressing need of a good network of roads in most of the states.

"(2) The War Department recognizes certain areas as more likely to be the theatre of military operations than other parts of the country. Every effort should be made to persuade the state road commissions to complete the network of through roads within these areas, and Federal aid should not be granted unless these roads conform in construction to the needs of the military transportation likely to be used in the zone of the advance.

"The areas in question are:

"(*a*) The area about Long Island, including most of the states of Rhode Island, Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and New York.

"(*b*) The area about Chesapeake Bay, including much of the states of New Jersey, Pennsylvania, Maryland, Virginia, North Carolina, and Delaware.

"(*c*) The Pacific Coast area, including California, Oregon, and Washington.

"(*d*) The Mexican border, including the southern part of the states of Texas, New Mexico, Arizona, and California.

"(*e*) The Great Lakes area, including the states of Ohio, Indiana, Michigan, Illinois, and parts of Wisconsin and Minnesota.

"The following requirements as to construction within the areas mentioned are recommended: (1) Roads to have a smooth, hard surface of broken stone or a pavement not less than 20 feet in width and capable of supporting the loads hereafter specified for bridges. (2) Grades not to exceed 5 per cent., except for short distances (less than 50 yards), where they shall not exceed 10 per cent. (3) Bridges to be of iron or masonry, and of type to support loads of a 6-inch howitzer (3000 pounds on front wheels and 6500 pounds on rear wheels, distance between axles 12 feet, width of wheel track 5 feet) or a 3-ton truck loaded (6000 pounds on front wheels, 8000 pounds on rear wheels, distance between axles about 10 feet, width between wheels, centre to centre, about 5 feet). In hilly country, where road foundations are necessarily in hardpan or rock, the importance of artificial surfacing is less important than the completion of a well-drained road bed joining the roads in the adjacent valleys; and it is therefore recommended that in such cases the completion of an unsurfaced graded road be completed before the requirement as to artificial surface is enforced.

"In general the projects already submitted by state road commissions comply with the first military requirements, as stated above, and it is believed that the Department of Agriculture would meet with little or no opposition in enforcing them as recommended."

In the light of military requirements, the matter of road control is emphasized just as it is by the ordinary economic require-

ments of the nation at large. It is the one really serious difficulty in our present road situation.

There are small groups of roads in specially created road districts, built with the proceeds of bond issues for which the district is liable. These roads are frequently under the sole charge of bond trustees. In the same county or township there may be other roads under the jurisdiction and control of the county commissioners. Still other roads in the same county may be jointly under the state and county, the latter being directly responsible for maintenance and the former having none but a supervisory authority so long as the county maintains properly. Then there may be a state road across the county over which the state has full control to build and maintain. Finally, there may be a Federal Aid road, and this road may be a section of any one in these previous categories. Over the Federal Aid road once constructed the Government has no control except that if the road be not properly maintained the Government may refuse further aid, at the end of four months, to the particular local unit responsible for the maintenance.

Under such a dispersion of authority it has been in the past, and doubtless will continue in the future to be, almost impossible to secure the systematic continuous construction and maintenance of important roads where the jurisdiction and the control of funds are lodged in so many different bodies. It is quite apparent, from the information that comes to us from Europe, that some centralized control of the roads over a considerable area will become imperative with the occurrence of special military needs. Roads will have to be built and maintained regardless of the local political boundaries, and it appears that any administrative unit less than the state would fail to serve adequately the demands that will arise. Such condition, however, is no more pertinent to the possible military uses of highways than to the present economic demand, and the same degree of centralized control is essential in peace as would be required in time of war. The gradual extension and development of this control is therefore warranted in peace as much as it would ever be, for only through such control can the completion of the most necessary roads largely considered be brought about, an advantageous uniformity of construction be attained, and adequate maintenance at all times be assured.

The general conclusion from these observations is that the planning and use of highways for military purposes introduces no new or essentially different principles and only a few altered assumptions. These assumptions are all in the direction of improved and heavier construction in most localities. Some states are already building on designs that are adequate in all respects except perhaps width of roadway and weight of bridges. But many are not doing so.

Some correlated system of roads in certain large areas should be laid out and, regardless of local units and political boundaries, constructed to form a large net of general control roads. A few trunk connections should be made with industrial centres in the interior.

Whether the United States is pursuing a policy in accordance with the demands of modern warfare can best be studied from the standpoint of the administration of the new Federal Aid Road Act which grants Federal aid to the various states. Under this act the states are required to organize a state highway department, submit projects for construction upon which it expects to expend Federal Aid funds, and guarantee that funds for the maintenance of completed projects will be provided by the local units having jurisdiction over the roads constructed.

After one year's operation all of the states have conformed to the requirements of the act and become the units with which the Federal Government coöperates. The several state highway departments are effective organizations for the designation, construction, and maintenance of certain selected roads. Previous to the enactment of this act most of the highly developed and thickly populated states had independent highway departments that had done very effective work. Many of these, such as Massachusetts, New York, Pennsylvania, New Hampshire, Maryland, Connecticut, and California, which have already comprehensive systems of improved roads based upon economical factors are in the groups outlined in the letter of the Secretary of War. Many civic organizations advocating through road construction have been influential in securing some degree of contiguous improvement. The War Department has also designated a few definite roads as essential to military activities, and many of these are being improved as fast as funds and economy will allow.

In those states along the coasts and border a large part of the Federal Aid is actually going on sections of a network that would serve adequately for military purposes. The design and type of construction are in general accord with the suggestions of the War Department. Of course, all such work is the result of voluntary coöperation. The Federal Government at the present time has no authority to force construction at any point or in any particular manner, and whatever good results are being obtained must fairly be attributed to similarity of engineering judgment, and to the harmonious relations and tactful conduct of affairs between the several governmental units concerned. There are certain directions in which the general program of road construction might be improved. The work among the various states might be more carefully correlated; the designs might be standardized in a few important details, and a program of work devised that will favor the completion of some articulated system of roads. Until such details have been worked out we shall not be able to close the final weak links that abound everywhere in our highway systems, or to provide adequate construction in poor or backward localities. Only when these things are accomplished will our highways at last possess the essential final elements that bring them up to their full effectiveness in time of peace and make them a dependable resource in time of war.

An Optical Ammeter. P. D. FOOTE. (*Journal of the Washington Academy of Sciences*, vol. 8, No. 4, p. 77, February 19, 1918.)—The high precision in the measurement of temperature possible by the use of a properly designed Holborn-Kurlbaum optical pyrometer equipped with a suitable pyrometer lamp is well recognized. If the lamps are operated below 1300° to 1500° C. the calibration of the pyrometer will not change appreciably after years of ordinary use. These two factors—accuracy of photometric settings and constancy in calibration of the lamps—permit the adaptation of this method of photometry to the measurement of current.

The range of current which can be measured by any one system of lamps exceeds 1 : 2, and lamps having filaments of different sizes may be used for a large range in value of currents. Assuming that a photometric match may be made with an error limit of 0.5 per cent., which is reasonable for precision photometry of this type, it can be shown that the current is determined with an error limit of 0.03 per cent.

HEATS OF DILUTION AND THEIR VARIATIONS WITH TEMPERATURE.*

BY

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1. *Enunciation of the Purpose of the Investigation.*—By thermodynamic calculations the variation of the heat of dilution of a solution with change of temperature is equal to the rate at which the heat capacity of the solution changes with the concentration. Previous determinations of the heats of dilution have failed to support this relation in some cases.[1] It is the object of this research to find out, if possible, whether this discrepancy is real or the result of experimental error.

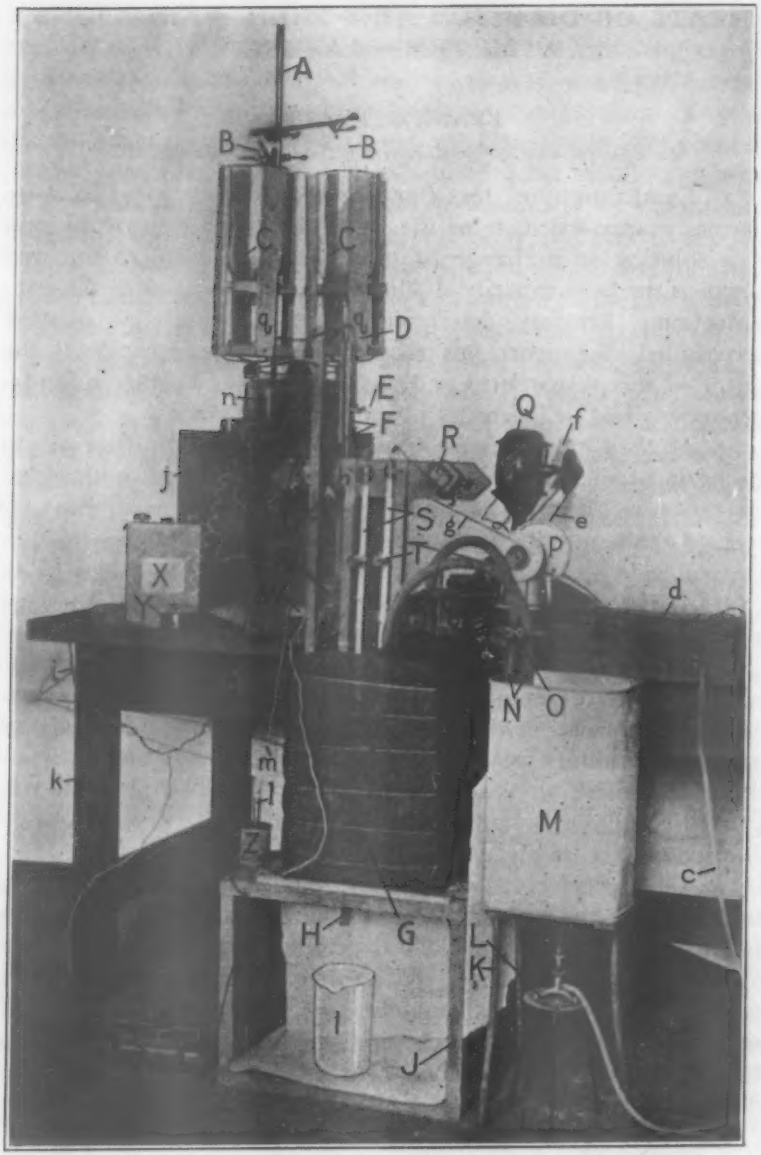
2. *Method of Obtaining Heats of Dilution.*—In determining the heats of dilution it is necessary to start with an initial concentration of the solution and measure the amounts of heat L_m evolved as the solution is diluted by adding to it mass m of water. The values of L thus obtained plotted against the values of m give a curve whose tangent at any point is the value of the heat of dilution for the corresponding concentration.

3. *Problem of Apparatus.*—Magie's experiments on heats of dilution were performed with silver calorimeters exposed to room temperature. On account of continual temperature change when the readings were taken it was necessary to make corrections, and these were somewhat uncertain. The problem was to devise a piece of apparatus that would measure the heat of dilution as accurately as possible. At the suggestion of Prof. H. L. Cooke, I decided to employ a method of continuous flow. In designing the several parts of the apparatus I was greatly assisted by Professor Cooke's experience and advice. The apparatus was planned so that either mercurial or platinum resistance thermometers could be used. After a thorough consideration of resistance thermometers they were abandoned in favor of mercurial thermometers, because the latter simplified the manipulation of the apparatus so that one person could use it.

* Communicated by the Author.

[1] Magie, "Heats of Dilution," *Physical Review*, vol. xxxv, October, 1912.

FIG. 1.



4. *Description of Apparatus.*—The principal parts of the apparatus were a delivery system by which equal masses of water and solution flowed continuously through the apparatus, and a thermostatic system by which the water and solution in separate tubes were brought to the same temperature, then mixed in a Dewar flask and the change in the temperature of the mixture noted. The complete arrangement of these systems is shown in Fig. 1, in which the several parts are marked with letters. Each part has the same letter in all the diagrams.

The delivery system consisted of two glass tanks, *C*, in which the liquids to be used were contained. These tanks were supported upon the pans of a balance, *n*, and the liquids were conducted from the tanks to the thermostatic system through rubber tubes which were supported at a point in line with the centre knife-edge to preserve the sensitiveness of the balance.

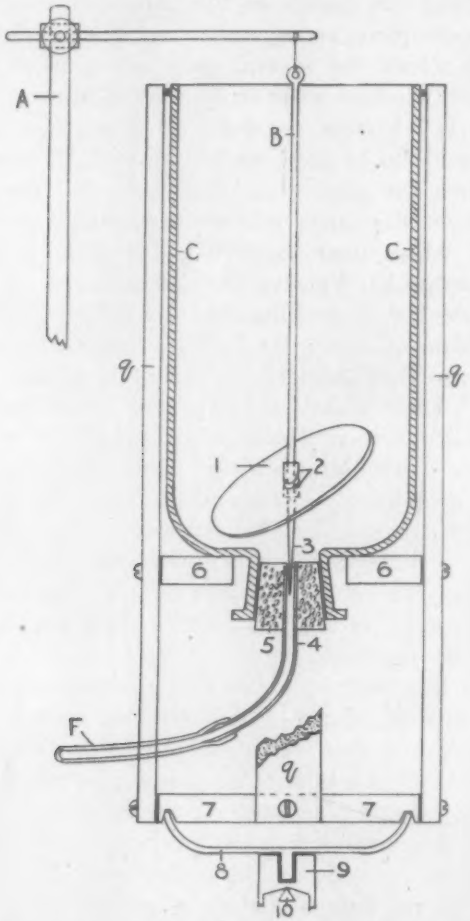
The device for controlling the flow of the liquids was the same in both tanks, hence the detailed diagram given in Fig. 2 shows only the right half of the delivery system. The stand, *A*, supports a small glass rod, *B*, on the lower end of which is a long conical valve, 3, which controls the rate of flow of the liquid. Valve 3 remains stationary while the tank moves up or down, thus decreasing or increasing the area of the opening through which the liquid leaves the tank. The tank having the greater mass of liquid will move down, opening its valve, and at the same time the other tank having less mass will move up and partly close its valve, thus automatically keeping the masses of liquids in the two tanks equal.

A test of this device showed that the balance oscillated continuously. Instead of two equal streams, there was a jet first from one tube and then from the other. A thin glass disc, 1, fastened to rod *B* in a horizontal position, decreased the number of vibrations, but did not overcome the difficulty. But by tilting the disc the least movement of the liquid up or down forced valve 3 against the side of the outlet tube, 4, causing friction which arrested the balance before it swung too far, and so the desired continuous flow was attained.

A detailed diagram of the thermostatic system is shown in Fig. 3. The several parts of this system were placed in a rectangular tank, 18, which was insulated with felt, 19, and filled with water. Two silver tubes, 9, received the liquids from

the delivery system and carried them to the mixing tube, 2, of the Dewar flask, 1. Each of these silver tubes was 2 millimetres in diameter and 3.8 metres long. This length of tubes gave the liquids which they conveyed abundant opportunity to acquire

FIG. 2.



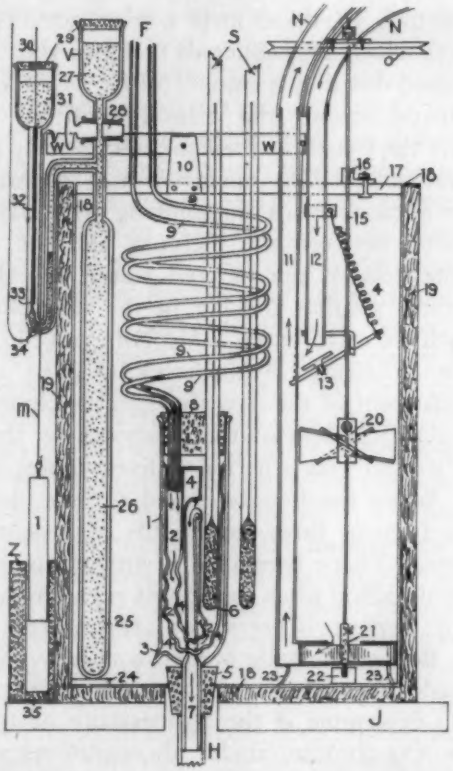
the constant temperature of the water in which the tubes were immersed. A vigorous circulation of the water was maintained by the revolving stirrer, 20.

The mixing tube was corrugated to aid in mixing the liquids, and was insulated by vacuum to prevent transfer of heat. Ar-

rows show the course of the mixture flowing around the thermometer bulb, 6, and out through the overflow tube, 7. The other thermometer, *S*, indicates the temperature of the water in the thermostat.

The temperature of the thermostat was maintained at the desired point by means of a circulatory system, which consisted

FIG. 3.



of a centrifugal pump, 21 (Fig. 3); an outlet tube, 11; a copper coil in the tank, *M* (Fig. 1); a return tube, 12 (Fig. 3); and a control valve, 13. The centrifugal pump forced a small amount of water from the thermostat through the system and back to the thermostat again. The copper coil was surrounded with ice or immersed in hot water, according as the desired temperature of the water in the thermostat was below or above 20° C.

In order that the right amount of cold or hot water might be delivered to the thermostat to maintain constant temperature, a sensitive control system was constructed. This system consisted of a long tube, 25 (Fig. 3), filled with toluene; a capillary U-tube, 32, containing mercury for closing an electric circuit which operated a solenoid, *Z*; and a control valve, 13, which was opened or closed by a solenoid plunger, *l*, acting through lever, *W*.

When the stopcock, 28, is closed the expansion of the toluene forces the mercury, 33, up to meet a wire, 30. This unites the wires 30 and 34 which are connected in series with a solenoid, *Z*. Wire 30 is pushed down by a cam, *U* (Fig. 1), at a constant rate until the push-rod holding the wire slips off the large part of the cam, breaks the circuit at the cam, and quickly pulls the wire out of the mercury. This operation was repeated every ten seconds. The advantages of this moving wire were the prevention of sparking between the mercury and the wire and the stopping of the flow of hot or cold water into the thermostat at short intervals so that the lag in the controller would not allow too much water to enter. Alcohol, 31 (Fig. 3), kept the surface of wire 30 clean. A pinchcock, *O* (Fig. 1), served for the rough adjustment of the flow through the circulatory system. With a careful adjustment of the pinchcock *O*, the temperature would not vary 0.001° for a period of five minutes while readings were taken. When the liquids ceased to flow the temperature would change two- or three-hundredths of a degree before the controller acted. There would be a similar amount of change in the opposite direction when the liquids began to flow.

5 *Tests of Correct Working of Apparatus.*—At first each silver tube in the thermostatic system was only 1.9 metres long. Tests were made by running water through these tubes separately and jointly to determine if the temperature of the water as it left the tubes was constant under all conditions when the temperature of the thermostat was kept constant. These tests showed that a change of five degrees in the temperature of the water as it entered these tubes produced a change of five-thousandths of a degree in the temperature of the water leaving the tubes. To prevent this change of temperature the length of these silver tubes was doubled. After this was done the temperature of the water leaving the tubes remained the same even with a change of

twenty degrees in the temperature of the water as it entered the tubes.

A strong solution of common salt was run through each tube separately and then through both at once, with the result that the thermometer always registered the same as when distilled water was used. Usually the thermometer in the Dewar flask registered four- or five-thousandths of a degree higher than the thermometer in the thermostat. This, no doubt, was due to the vigorous stirring in the mixing tube. If the thermometer in the thermostat stood at 15.000° C., the thermometer in the Dewar flask always registered 15.004° C. when water or salt solution alone flowed through the apparatus.

When distilled water flowed through one tube and an equal mass of salt solution flowed through the other (the thermometer in the thermostat still standing at 15°), the thermometer in the Dewar flask changed from 15.004° C. to some other temperature —for example, to 14.754° C.—owing to the heat of dilution, and continued to register this temperature until the tanks of the delivery system were empty. This zero method allowed the 0.250° C. change of temperature to be measured by the thermometer in the Dewar flask alone, hence no correction for slight differences in the two thermometers was needed.

The contents of the Dewar flask were only a few thousandths of a degree lower in temperature than the surrounding thermostat, hence no radiation correction was necessary. When the flow of liquids stopped, the thermometer in the mixing tube continued to register the same temperature for some minutes, showing good insulation. Even the heat arising from the friction of the liquids running through the mixing tube was compensated by the zero method. Electric hammers were arranged to tap both thermometers before each reading was taken, magnifying glasses fastened to each thermometer aided materially in estimating to thousandths of a degree, and the fact that both thermometers remained constant for several minutes while readings were taken inspired great confidence in the correctness of the readings.

6. *Method of Taking Measurements.*—In cases when the solubility permitted, the initial solution consisted of 25 gramme-molecules of water to one gramme-molecule of salt. The initial concentration, on the convention that $c = 10000/N$, is therefore 400. By running this solution through the apparatus and an equal

mass of water the concentration is changed to 188 in the case of sodium chloride and to different values for other salts. In order to have uniformity in tabulating measurements, the change in temperature resulting from this first dilution was placed in a column marked 1. When this solution was diluted a second time by adding again a mass of water equal to the mass of the solution, the change of temperature was placed under the heading marked ½, the third dilution under ¼, etc. This process was continued until the solution was so dilute that no change of temperature could be detected.

There was no advantage in repeating the measurements at the same temperature, because the results were always the same. But since there is a continuous change in the heat of dilution as the initial temperature is varied, it was of advantage to make a large numbers of measurements with a small increase of temperature in each successive measurement. A variation of two degrees for the chlorides and of five degrees for the other solutions was used. The change in temperature resulting from dilution was plotted against the initial temperature of the solution and water before mixing and a smooth curve passed through these points. This method tended to eliminate small errors in the thermometer by using a different part of the scale of the thermometer each time. It also compensated for the personal factor, since a different number was estimated each time.

7. *Method of Computing Heats of Dilution.*—As the method of calculation was the same for all solutions, a full explanation for any one of them, *e.g.*, sodium chloride, is sufficient. The concentrations for the several dilutions of the sodium chloride solution were calculated and found to be 400, 188, 91.1, 44.9, and 22.3. The heat capacities corresponding to these concentrations were interpolated from tables given by W. F. Magie, *Physical Review*, vol. xxv, No. 3, and were found to be 448.2, 949.5, 1864, 3994.3, and 8043.8, respectively. The heat capacity multiplied by the change of temperature gives the number of gramme-calories of heat which must be introduced into the solution or withdrawn from it to keep the temperature constant.

To compute the heat of dilution of sodium chloride at 10° C., the point is found at which curve 1 (Plate A) cuts the 10° line. This is at −0.297°. This number, multiplied by the heat capacity 949.5, gives −282 calories, which is the value of L for concen-

PLATE A.

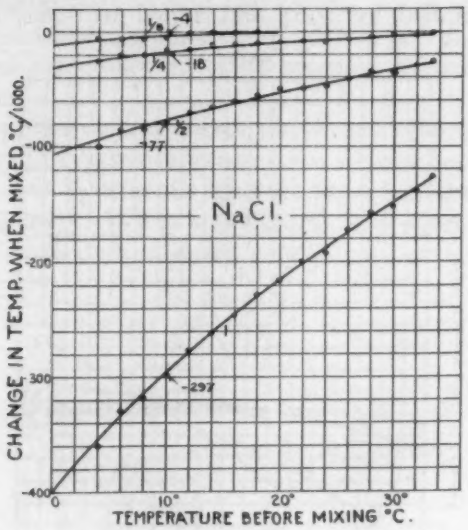
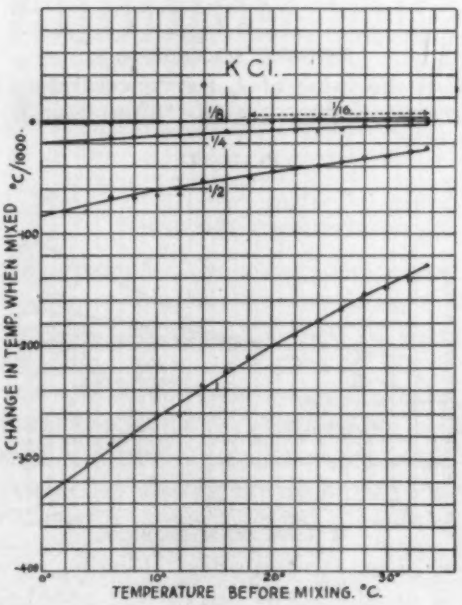
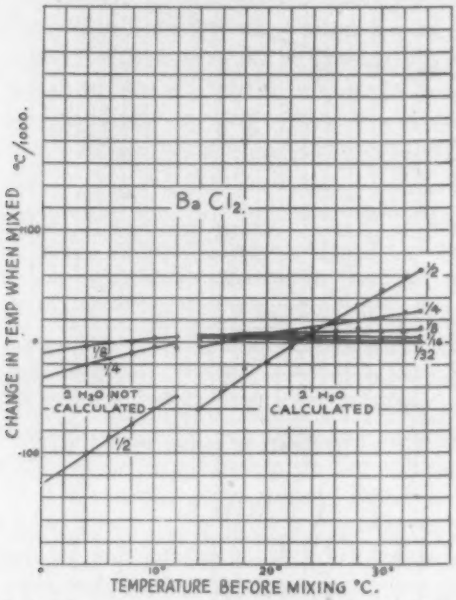


PLATE B.



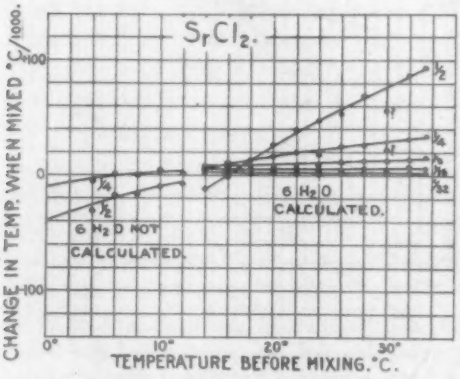
tration 188. Curve ½ cuts the 10° line at −0.077°, and this number, multiplied by 1964 and added to −282, equals −433

PLATE C.



calories, which is the value of L for concentration 91.1. Curve ¼ cuts at −0.018°. This number, multiplied by 3994.3 and

PLATE D.

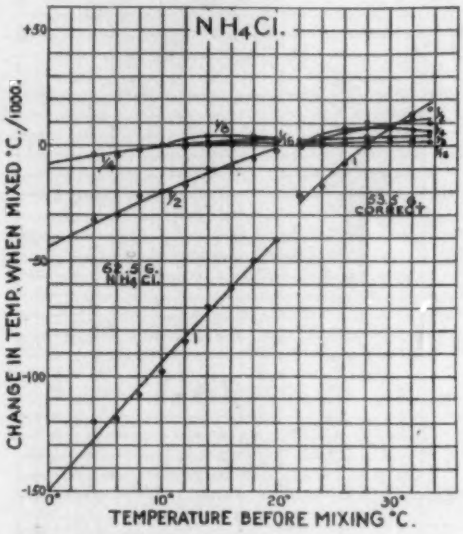


added to −433, gives −505 calories. Finally, curve ⅛ cuts at −0.004°, which, multliplied by 8043.8 and added to −505, gives

−537 calories. These values of L were plotted against the corresponding concentrations and the several points connected by a smooth curve which gave the curve marked 10° in Plate F. This same process was followed in determining the curves for other temperatures.

In part of the measurements for barium and strontium chloride the water of crystallization was not allowed for. At temperatures below 20° by mistake nine grammes too much ammonium chloride was used. It was supposed to be possible to interpolate the correct values from these results until it was too late to

PLATE E.



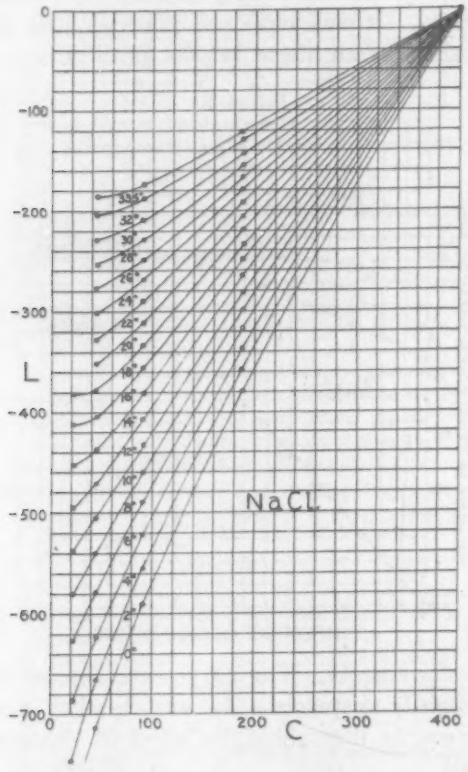
repeat the measurements. The curves are similar to the correct curves, but slightly displaced. It was thought worth while to give these curves, as they show the effect of changing the initial concentration.

Sodium and potassium hydroxide have great affinity for water. As it was impossible to determine the weight of water in the samples used, a solution of each was made and the concentration was determined by finding the density of the solution. The first solution contained 13.5 gramme-molecules of water to one gramme-molecule of sodium hydroxide. The second solution contained 15.2 gramme-molecules of water to one gramme-mole-

cule of potassium hydroxide. These concentrations were about double the initial concentration used in sodium chloride, hence the first curve is marked 2.

Barium nitrate dissolves slightly in water; thus one-eighth of a gramme-molecule of this salt was dissolved in 25 gramme-molecules of water for the initial solution.

PLATE F.



8. *Statement of Relations to be Examined.*—The formula to be tested is

$$\frac{dl}{d\theta} = -\frac{dH}{dm} \quad \text{(a)}$$

in which l stands for the heat of dilution and is positive when heat has to be removed to keep the temperature θ constant as dilution proceeds. H is the heat capacity of the system, consist-

PLATE G.

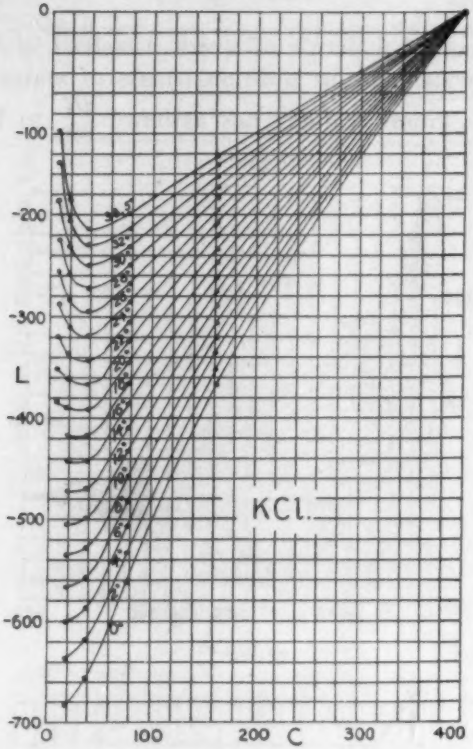
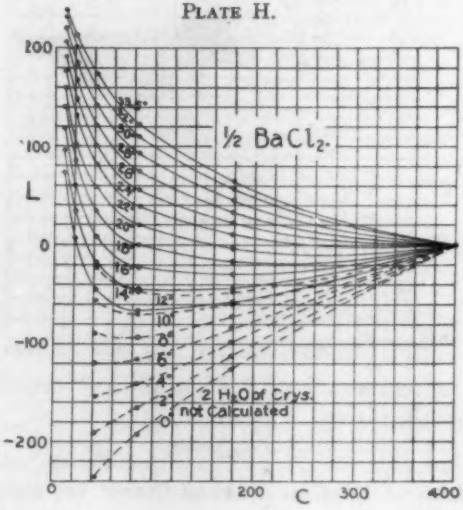


PLATE H.



ing of one gramme-molecule of a salt dissolved in N gramme-molecules of water and an additional mass of water. m is the mass of the solution. Magie has assumed $\frac{dH}{dm}$ to be constant

PLATE I.

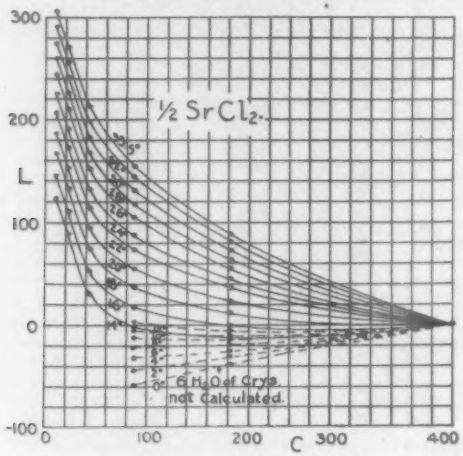
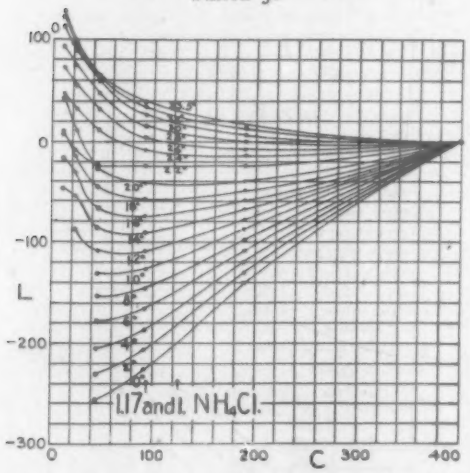


PLATE J.



with respect to temperature.[2] This allows formula (a) to be integrated into the form

$$l_2 - l_1 = -a\,(\theta_2 - \theta_1) \quad \ldots\ldots\ldots\

PLATE K.

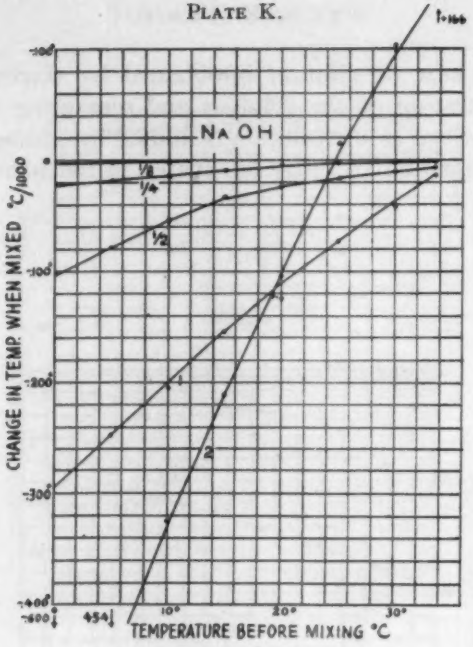
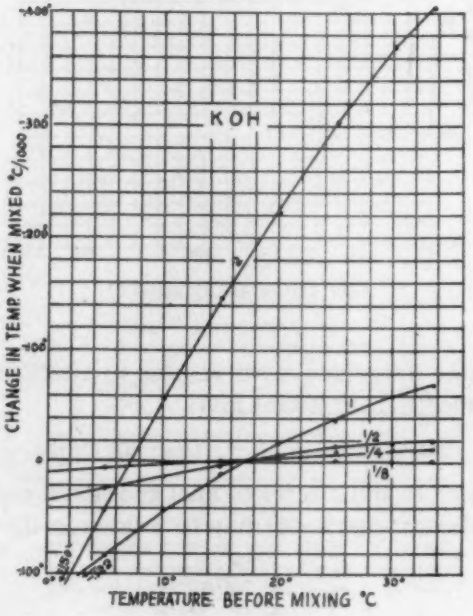


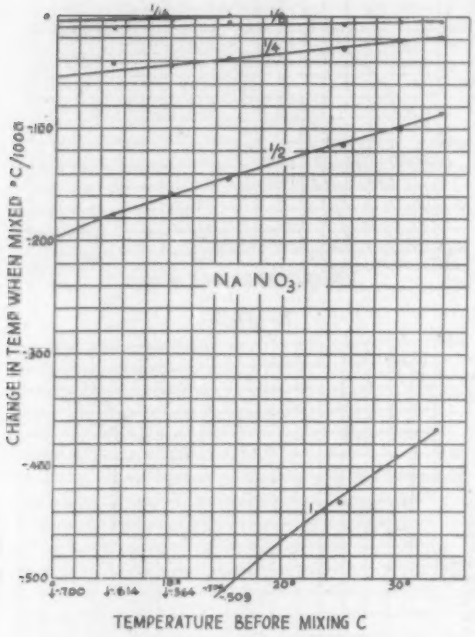
PLATE L.



Since the heat of dilution is obtained by starting with an initial concentration of the solution and measuring the amount of heat L_m evolved as the solution is diluted by adding to it mass m of water, equation (b) may be written in the form:

$$\frac{dL}{dm_2} - \frac{dL}{dm_1} = -\frac{dH}{dm}(\theta_2 - \theta_1) \quad \ldots\ldots\ldots\ldots\ldots\ldots (c)$$

PLATE M.



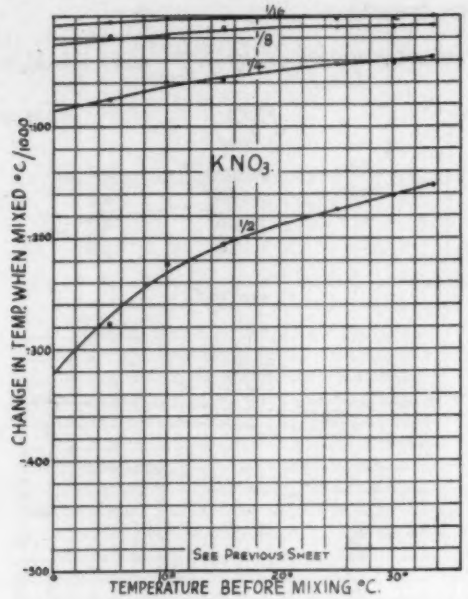
This expression integrated with respect to mass and the temperature assumed to be constant gives

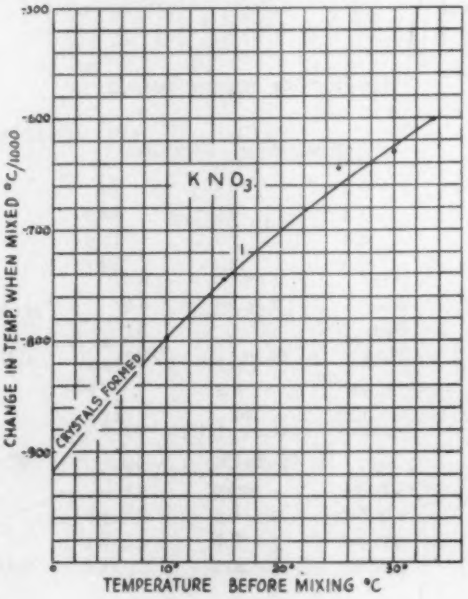
$$(L_m - L_o)_2 - (L_m - L_o)_1 = -(H_m - H_o)(\theta_2 - \theta_1) \quad \ldots\ldots\ldots\ldots\ldots\ldots (d)$$

where subscripts m and o refer to final and initial concentrations. Since L_o equals o, formula (d) may be written in the form

$$\frac{L_2 - L_1}{\theta_2 - \theta_1} = -(H_m - H_o) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (e)$$

PLATE N.


1/16
1/8
1/4
KNO3.
1/2
-100
-200
-300
-400
-500
CHANGE IN TEMP. WHEN MIXED °C./1000
SEE PREVIOUS SHEET
0
10°
20°
30°
TEMPERATURE BEFORE MIXING °C.


-500
-600
-700
-800
-900
KNO3.
1
CRYSTALS FORMED
CHANGE IN TEMP. WHEN MIXED °C./1000
0
10°
20°
30°
TEMPERATURE BEFORE MIXING °C

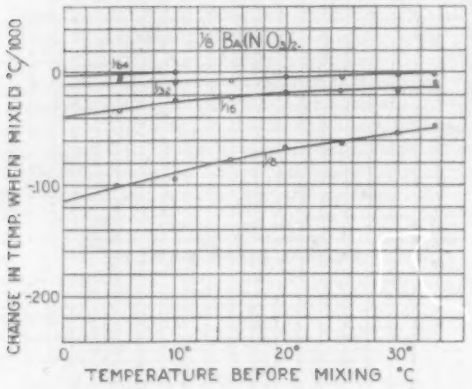
The following tables show the values of equation (e) for the several solutions tested:

Tables for Values of $\frac{L_2 - L_1}{\theta_2 - \theta_1}$ and $-(H_2 - H_1)$.

NaCl. $H = 448.2$

θ_2-θ_1	200	100	50
10–4	8.5	14.0	19.2
20–10	7.0	11.8	14.9
30–20	5.7	9.8	12.1
$-(H_2-H_1)$	6.0	10.2	13.8

PLATE O.



KCl. $H = 440.3$

θ_2-θ_1	200	100	50	25
10–4	6.4	10.5	14	15.7
20–10	5.4	9.7	12.5	14
30–20	4.6	7.2	11.9	12.2
$-(H_2-H_1)$	8.3	13.1	18.1	22.2

½ $BaCl_2$. $H = 430.6$

θ_2-θ_1	200	100	50	25
24–14	6	9.7	12.2	13
33.5–25	5.2	8.2	9.7	8.9
$-(H_2-H_1)$	6.2	10	13.7	16.6

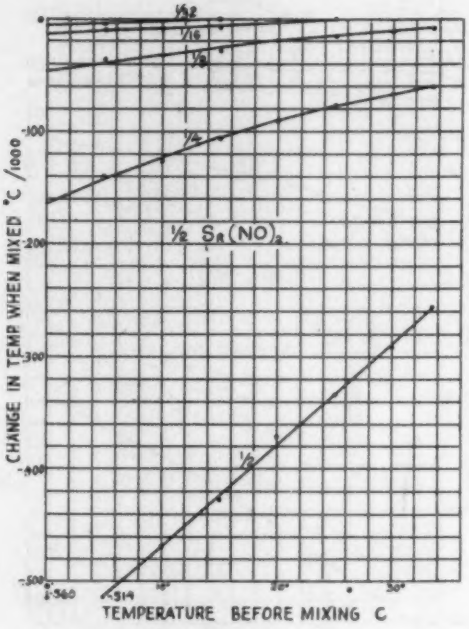
½ $SrCl_2$. $H = 430$

θ_2-θ_1	200	100	50
24–14	5.2	8.5	9.8
33.5–24	4.2	6.6	8.1
$-(H_2-H_1)$	6	10.4	15.1

NH.Cl. $H = 445$

$\theta_2-\theta_1$	200	100	50
33.5–22	3.3	5.7	5.6
$-(H_2-H_1)$	2	4	6

PLATE P.



NaOH. (1.847) $H = 441$

$\theta_2-\theta_1$	400	200	100	50
10–5	11.6	20.4	31.0	37.4
20–10	9.8	19.3	25.4	32.1
30–20	7.8	16.6	19.6	22.6
$-(H_2-H_1)$	5.88	10.88	15.88	18.88

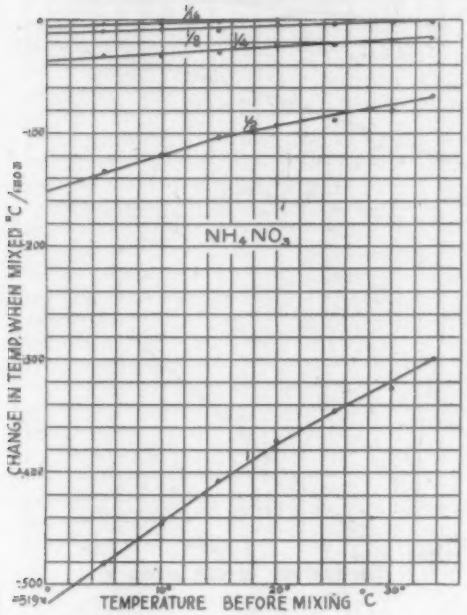
KOH. (1.645) $H = 421$

$\theta_2-\theta_1$	400	200	100	50
10–5	7.2	17	24.2	28.4
20–10	6.8	14.4	20.2	24.3
30–20	5.5	11.3	16.7	19.2
$-(H_2-H_1)$	9.4	16.4	22.4	26.4

$NaNO_3$ $H = 467$

$\theta_2-\theta_1$	200	100	50	25
10–5	11.2	16	20.8	22.8
20–10	8.4	15.2	21.3	22.2
30–20	6.8	13.6	18.8	19.4
$-(H_2-H_1)$	8.8	14.5	19.0	23.4

PLATE Q.



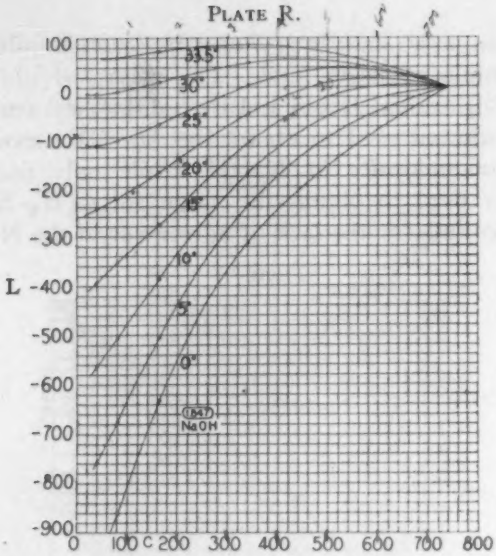
KNO_3. $H = 462$

$\theta_2-\theta_1$	200	100	50	25
10–5	10.4	24	35.2	45.2
20–10	8.8	17.2	23.8	27.4
30–20	6.8	12	16.2	17.8
$-(H_2-H_1)$	9.9	18.6	25.2	31.2

⅛ $Ba(NO_3)_2$. $H = 448.9$

$\theta_2-\theta_1$	200	100	50
10–5	2	4.2	6.8
20–10	2	3.5	5.2
30–20	1.3	2.1	3.2
$-(H_2-H_1)$	1.8	3.9	For ½ $Ba(NO_3)_2$

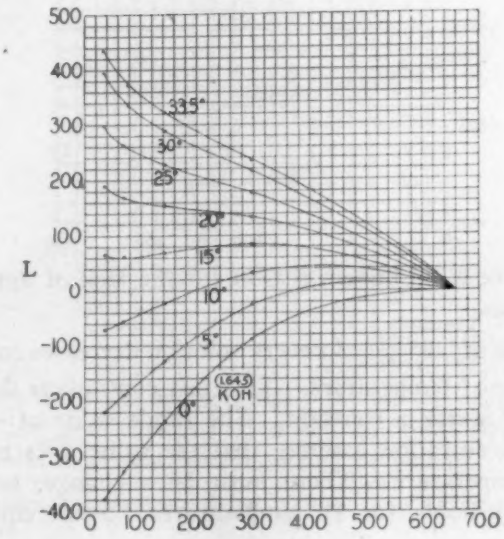
PLATE R.



½ $Sr(NO_3)_2$. $H = 452.7$

$\theta_2-\theta_1$	200	100	50
10–5	8.4	16.4	20.8
20–10	7.6	14.4	19.2
30–20	7.8	12.4	17.2
$-(H_2-H_1)$	7.7	11.7	15.0

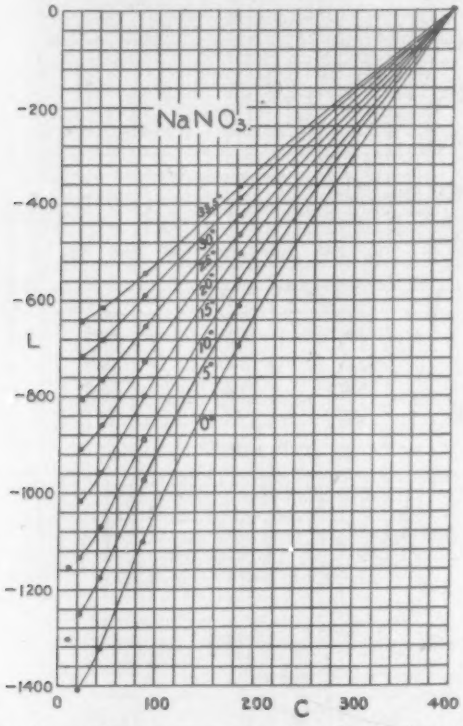
PLATE S.



C

9. *Discussion of Results of Tests of Formula.*—In a general way the formula seems to hold. The values of $-(H_2-H_1)$ in KCl and $SrCl_2$ are too large, and in NaOH they are too small. The initial solution used to obtain the (L, C) curve contained 1.847 gramme-molecules of NaOH, while only one gramme-molecule was used to obtain the value for $-(H_2-H_1)$. This difference accounts for the lack of agreement in the NaOH solu-

PLATE T.



tion, but there is no known reason for the lack of agreement in the other two.

The value of $\frac{L_2-L_1}{\theta_2-\theta_1}$ in every solution decreases considerably with increase of temperature. This fact contradicts the assumption that dH/dm is a constant. The single value of $-(H_2-H_1)$ for each concentration assumes that the value does not change with the temperature. There must be a change, however, if equation (e) holds for all temperatures. Since equation (e)

was found by assuming that dH/dm was constant, it is necessary to modify equation (e). It is a well-known fact that the specific heat of water decreases a small amount between 0° and 33°, and, since a large part of the system is water, the heat capacity

PLATE U.

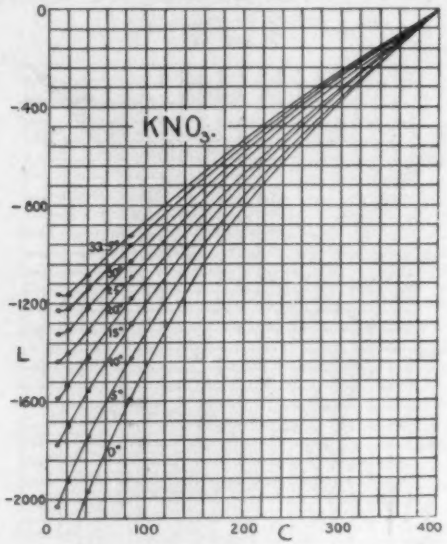
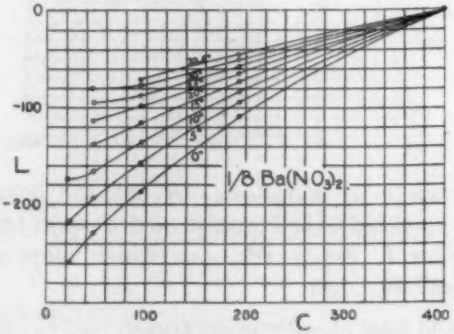


PLATE V.

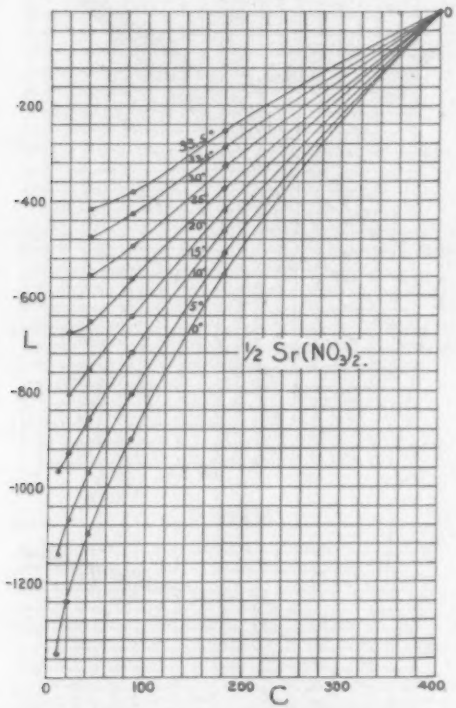


must change with the temperature. Teudt has shown that the change in the heat capacity of a salt solution with change of temperature is in general less than that of water.[3]

[3] Inaug. Diss. Erlangen, *Beiblatter*, xxiv, p. 1104 (1900).

The specific heats of the several salts increase with increase of temperature, hence, if the properties of a concentrated solution are additive, we may assume the specific heat of the solution to be constant, or more nearly so than water. As there is no very definite knowledge on this point, suppose we assume the specific heat of a concentrated salt solution to be constant.

PLATE W.



10. *Modification of Relations.*—When the heat capacity of the solution is assumed to be constant with respect to the temperature it is possible to derive relations which more nearly fit the experimental values. Let

M = the total mass of water in the system.
m = the mass of water in the solution.
$M-m$ = the mass of water outside of the solution.
h = the heat capacity of the solution.
S = the specific heat of the solution.
σ = the specific heat of the water outside of the solution.

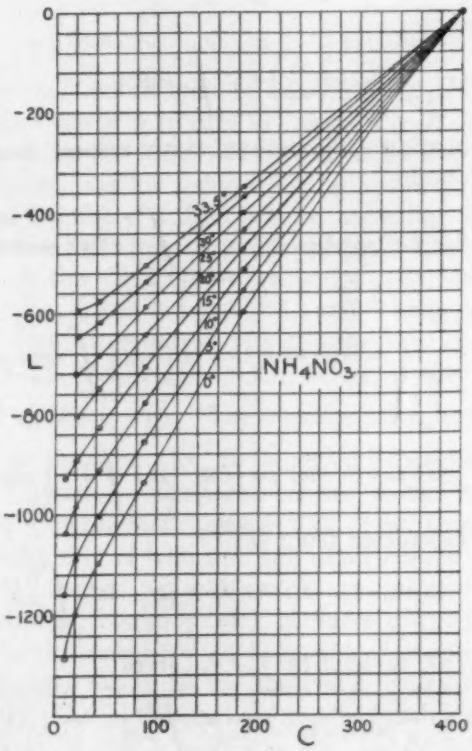
Then $H_o = Sm + \sigma\,(M - n)$. A small mass of water, dm, transferred from the supply outside of the solution, to the solution gives the heat capacity

$$H_1 = (S + \frac{dS}{dm}\,dm)\,(m + dm) + \sigma\,(M - m - dm)$$

and

$$H_1 - H_o = Sdm - \sigma\,dm + m\frac{ds}{dm}dm$$

PLATE X.



but

$$H_1 - H_o = dH$$

therefore

$$\frac{dH}{dm} = S - \sigma + m\frac{dS}{dm} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (f)$$

$h = mS$ and $dh = mdS + Sdm$

therefore

$$\frac{dh}{dm} = m\frac{dS}{dm} + S$$

This equation, substituted in (f), gives

$$\frac{dH}{dm} = \frac{dh}{dm} - \sigma$$

This value of $\frac{dH}{dm}$, substituted in (a), gives

$$\frac{dl}{d\theta} = -\left(\frac{dh}{dm} - \sigma\right) \quad \text{(g)}$$

By integration

$$l = -\left(\frac{dh}{dm}\right)\theta + \int \sigma\, d\theta + e$$

When this equation is integrated with respect to m, and θ is constant, we obtain

$$L_1 - L_o = -(h_1 h_o) - (\theta_1) + \int\int \sigma\, d\theta\, dm + edm \quad \text{(h)}$$

or

$$= -(h_1 - h_o)(\theta_1) + (M_1 - M_o)\int \sigma d\theta + edm$$

and

$$L_2 - L_o = (h_1 - h_o)(\theta_2) + (M_1 - M_o)\int \sigma d\theta + edm \quad \text{(i)}$$

When (h) is subtracted from (i),

$$L_2 - L_1 = (h_1 - h_o)(\theta_2 - \theta_1) + (M_1 - M_o)\int_{\theta_1}^{\theta_2} \sigma\, d\theta \quad \text{(j)}$$

Equation (j), divided by $\theta_2 - \theta_1$, gives

$$\frac{L_2 - L_1}{\theta_2 - \theta_1} = (h_1 - h_0) + \frac{M_1 - M_0}{\theta_2 - \theta_1}\int_{\theta_1}^{\theta_2} \sigma d\theta \quad \text{(k)}$$

The left sides of equation (k) and (e) are equal. The right side of equation (k) shows the variation of $-(H_2 - H_1)$ which must be used in the cases tested, when the change in the specific heat of water with respect to the temperature is taken into account.

The formula for the specific heat of water proposed by Callendar[4] for temperatures between 0° and 20° is

$$\sigma = 0.9982 + 0.0000045(t-40)^2 + 0.0000005(20-t)^3 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (l)$$

and for temperatures between 20° and 60° the last term is omitted.

If equation (l) is multiplied by $d\theta$ and integrated between the limits θ_1 and θ_2, we have

$$\int_{\theta_1}^{\theta_2} \sigma \, d\theta = 0.9982\,(\theta_2 - \theta_1) + 0.0000045 \left\{ \frac{1}{3}(t_2 - 40)^3 - \frac{1}{3}(t_1 - 40)^3 \right\}$$

$$+ 0.0000005 \left\{ \frac{1}{4}(20 - t_1)^4 - \frac{1}{4}(20 - t_2)^4 \right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots (m)$$

Equation (m), substituted in equation (k), gives the complete expression which is to take the place of $-(H_2-H_1)$.

The value of h_0 for NaCL at concentration 400 is 448.2, and for concentration 200 the value of h_1 is 892.2. The difference between these numbers is 444, which, according to the theory proposed, is constant for all temperatures. The value of the second term in the right side of equation (k) varies with the temperature. Let θ_1 and t_1 equal 4° C. and θ_2 and t_2 equal 10° C.; then the last term in equation (k) becomes 451.9. The difference between 451.9 and 444 is 7.9, which is the value of the right side of equation (k). The corresponding value of $\frac{L_2 - L_1}{\theta_2 - \theta_1}$ the left side of equation (k), is found by experiment to be 8.5. In a similar manner for temperatures 10° to 20° the right side is 6.5 and the experimental value is 7.0. For temperatures 20° to 30° the right side is 5.66 and the experimental value is 5.7. The difference between 7.9 and 5.66 is 2.2, which is the change in the left side of equation (k) between 0° and 30°. This change will be the same for all solutions at concentration 200. While it is slightly too small for the NaCl, it is about right for KCl and KOH. At concentrations 100 this difference would be doubled, or 4.4. At 50 it would be 8.8, and at 25 it would be 17.6. With the exception of KNO_3, which has a very large variation, these last numbers are too large. As the solution becomes more dilute it is highly probable that the specific heat of the solution changes similarly to water, which would tend to reduce

[4] *Phil. Trans.* R. S. (1902), clxix, 142.

PLATE 1.

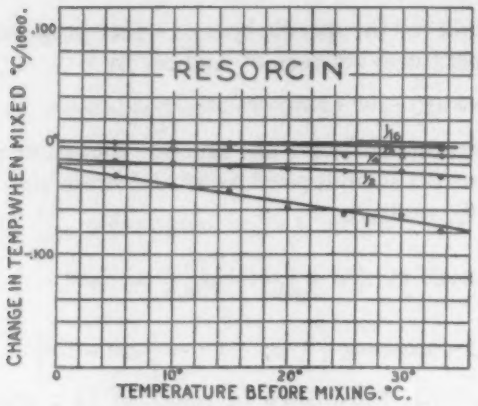


PLATE 2.

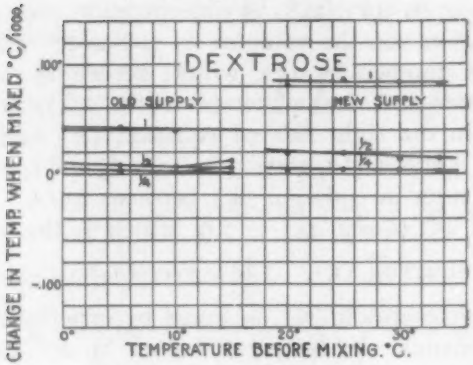


PLATE 3.

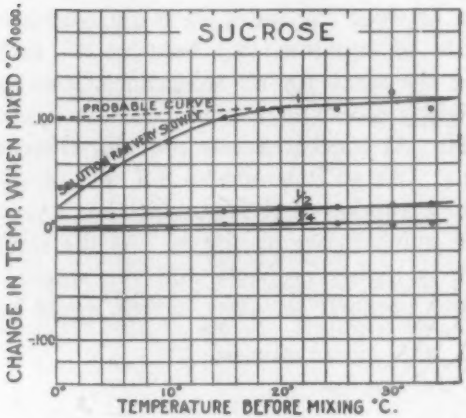


PLATE 4.

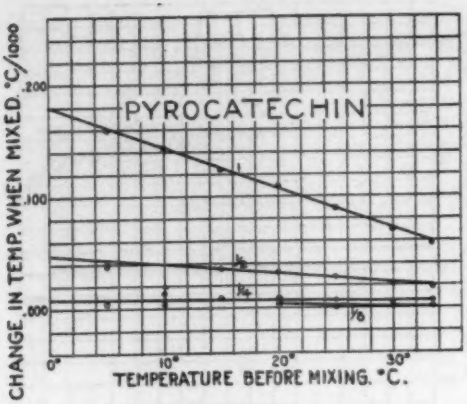


PLATE 5.

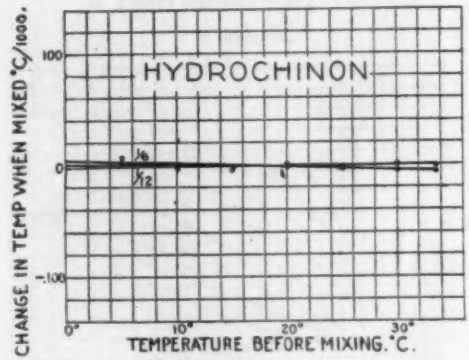


PLATE 6.

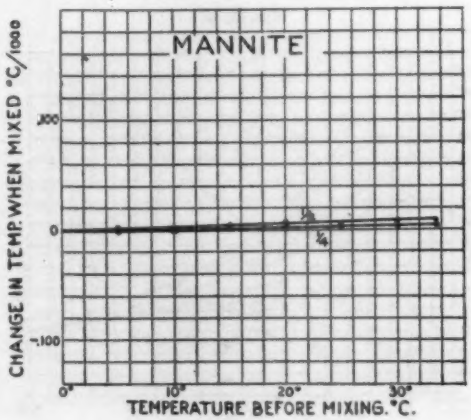


PLATE 7.

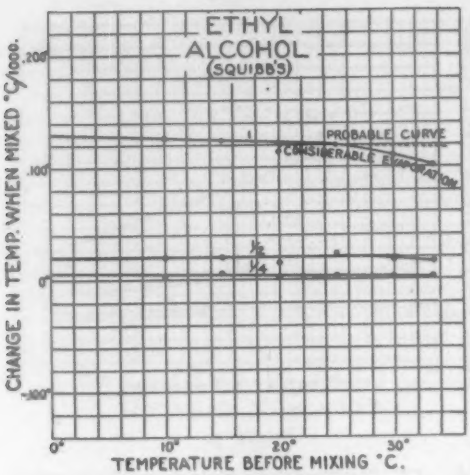


PLATE 8.

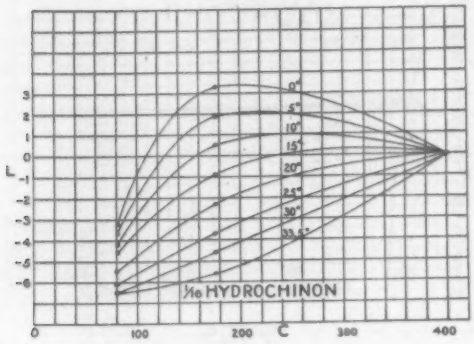


PLATE 9.

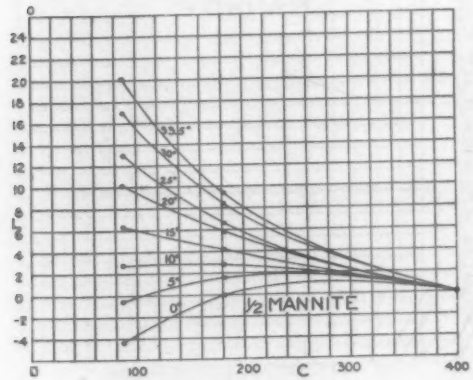


PLATE 10.

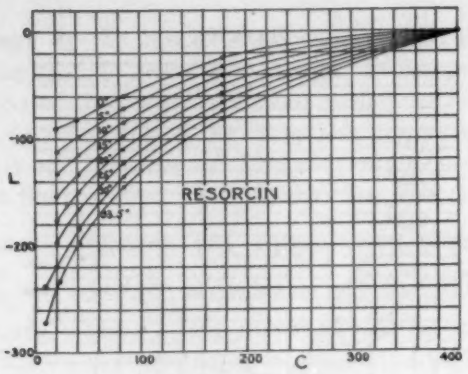


PLATE 11.

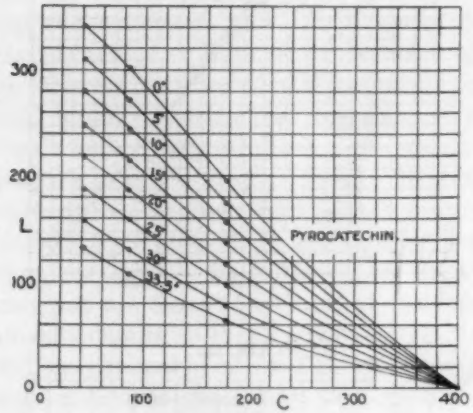


PLATE 12.

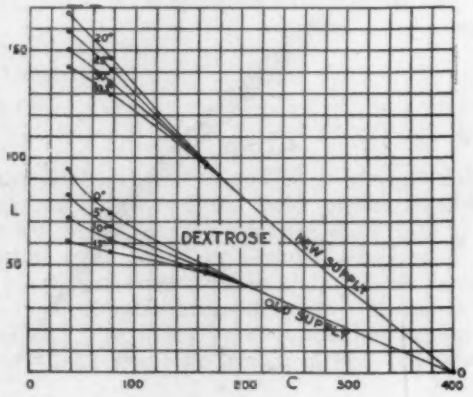


PLATE 13.

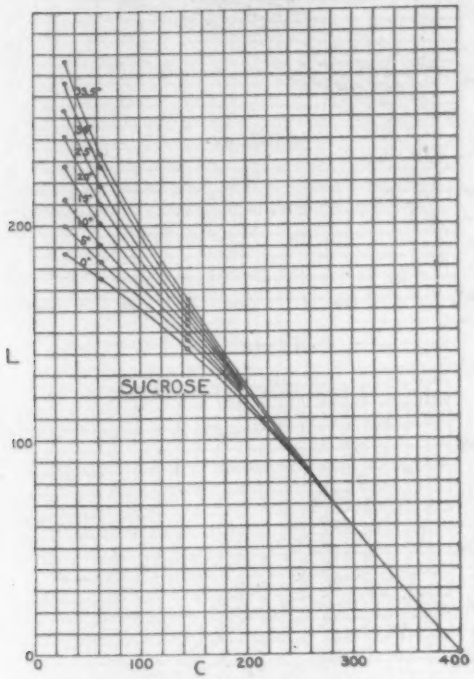
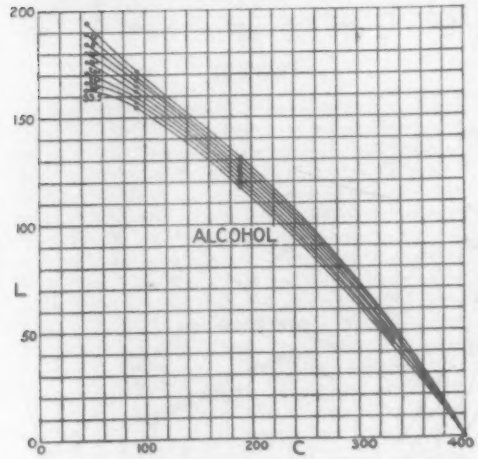


PLATE 14.



these numbers at the more dilute concentrations. When the change in the specific heats with respect to temperature for all concentrations of the several solutions is definitely known it may be possible to account for all the exceptions found in these results.

11. *Heats of Dilution of Non-electrolytes.*—The point of interest with the non-electrolytes is that the H is constant for all concentrations. Equation (a) equals zero, since $\frac{dH}{dm} = a = 0$, therefore $\frac{dl}{\partial d} = 0$ and $l = c$, a constant, and should not vary with the temperature. The (L, C) curves should be parallel and the curves in Plates 1 to 7 should be horizontal straight lines. The curves in Plates 1 to 7 are straight lines, but none of them is exactly horizontal. Resorcin and pyrocatechin show considerable variation from the horizontal, and this produces the fan-shaped (L, C) curves. If the (L, C) curves of the non-electrolytes were plotted to the same scale as the (L, C) curves of the electrolytes the lines would be very much closer together. The use of the much larger scale with several of the non-electrolytes exaggerates the small departure from the theory. It is of interest to note that, while the majority of the lines in Plates 1 to 7 slant slightly downward toward the right, there are two or three that slant upward toward the right. This proves conclusively that this slight variation was not due to any fault of the apparatus.

I take this opportunity to thank Prof. W. F. Magie for placing a room and the equipment of the Palmer Physical Laboratory at my disposal. I wish to express my appreciation of his kindly assistance and to acknowledge the many suggestions received from him and Prof. H. L. Cooke while carrying on the work.

PALMER PHYSICAL LABORATORY,
Princeton University,
June, 1917.

Pure Sheet Nickel. ANON. (*The Iron Age*, vol. 101, No. 11, p. 690, March 14, 1918.)—Pure solid nickel should not be confounded with the much inferior metals usually sold as nickel, which consist mostly of steel, brass, or German silver with a thin plating of nickel. This plating wears off in a short time, leaving manufactured articles unserviceable and worthless. Nickel is essentially an American product. For many years past it has been a general practice to use ore which has been mined in this country and Canada.

having it fabricated into its various forms by European manufacturers. Previous to the war most of the material imported into this country as foreign stock was the American metal worked into the form of sheet, strip, and finished articles of manufacture by foreign concerns. Until a few years ago there had never been any appreciation of the many points of vantage of this metal for almost innumerable purposes, and consequently there had never been any adequate facilities for rolling it into large sheets.

Pure nickel does not rust or oxidize, and consequently every danger of poisoning generally caused by verdigris is eliminated. Neither will the metal tarnish like silver or some of the alloys, such as German silver, and, even though the surface be injured, there is no danger of corrosion resulting as in a plated article. Furthermore, the tedious and expensive plating operations required for articles made of other metals is entirely abolished. This makes the metal particularly adaptable for use in the manufacture of cooking utensils or food-handling equipment, where the highest precautions must always be observed to avoid infection and poisoning. This advantage of perfect safety lasts as long as the article itself, whereas plated utensils must be discarded or replated upon the appearance of the slightest break in the nickel protecting surface. While not so good a heat conductor as aluminum, nickel utensils are made of a thinner material, which more than overcomes the difference. Pure nickel has a melting-point of about 2600° F., whereas aluminum has one of about 1200°. There is not the same possibility of this metal being softened under constant use. The metal is also much more resistant to the action of the acids commonly found in food products. The fine silver-like appearance of pure nickel does not change in use, and the cleaning of these utensils is as easy and simple as possible, hot water or soda being quite sufficient.

In the chemical field there are many uses for this metal. The surface of pure nickel is not attacked by acids or alkalies in the dilute form usually encountered in ordinary service. In fact, it is practically immune to the attacks of all alkalies, regardless of their strength, and is largely resistant to the action of most acids. Nickel has a high tensile strength, and in the sheet form, being homogeneous throughout, is ductile and easily formed by spinning or stamping. No special equipment is necessary for manufacturing articles from these sheets, the same tools and metals being employed as with German silver and hard alloys. The great increase in the cost of copper and its products has brought pure nickel to a point where it can be compared with favorably as to initial cost, without counting long life and service.

AN IMPROVED PROGRESS-OF-WORK CHART.*

BY

F. J. SCHLINK, M.E.,

Associate Physicist, U. S. Bureau of Standards.

IN order to supply a form of record for use in central office follow-up of important and urgent testing work, the writer developed the simple and compact type of running record chart shown herewith. It is thought that this may be of interest and value to industrial plants, and to other testing laboratories, for similar purposes.

The example given applies expressly to the recording of progress of work in a testing or investigational laboratory. As will be shown later, however, the identical principles are applicable, with the same convenience and efficacy, to following the progress of manufacturing operations. It is equally well adapted to scheduling the make-up of publications, and to recording the stage reached in the adjustment of a customer's complaint or claim.

This chart, shown in the appended figure, is practically three-dimensional in effect. The vertical coördinate defines the material tested and its references; the horizontal coördinate is that of date; while the third, which is the phase or stage of progress that the work has reached, is given by a straight line drawn in the appropriate direction in the proper date square.

A specific example of such a record is given in the illustration, in which the following actions are recorded:

Request for the test, dated	October	3
Request received	"	4
Material received	"	6
Test begun	"	6
Report prepared	"	9
Report mailed	"	10
Material reshipped	"	10

(In case the material tested is returned after completion of the work)

* Communicated by the Bureau of Standards.

In addition we note that there was received in regard to the test

An incoming communication of October 6,

followed by

An outgoing communication (in reply) of October 7

(in the case of this and the preceding record, the direction of the arrow-head on the record line indicates whether the correspondence is incoming or outgoing)

Thus each advance in the status of the work is noted by a rotation of the record mark through 45 degrees in the clockwise direction.

In case the work is followed up before completion, and a promise is given as to the date on which the report may be expected, this is indicated by a dotted line in the space corresponding to the promised date, as on October 8 in the example given. If the promised date is fulfilled, a solid line is simply drawn over the dotted line; if not, the error in the estimate is evident on the chart. When a date upon which the work should be followed up is decided upon at the time it is entered, or perhaps later when a special reason arises for so doing, this may be conveniently indicated by drawing a small circle about the central dot. When that date arrives, the horizontal diameter of the circle is drawn in, to show that the follow-up has been carried out: this is exemplified in the date space for the 7th in the example.

In the case of work carried over from one month to the next, suitable written notes are added in the vacant portions of the date ruling to avoid rewriting, on the next sheet, of data already recorded, or, if desired, the entry may be made in the usual way in a date square with the addition of the name of the month, abbreviated.

The same form can conveniently be adapted to manufacturing processes by altering the significance of the positions in which the lines are drawn. In the case of a manufacturing plant, for example, the meaning of the eight positions of the record mark may be as follows; the manner of recording will otherwise be exactly the same as described above.

1. Order dated.
2. Order received.
3. Drawings begun.
4. Drawings to shop.
5. Shop work finished.
6. Material delivered to shipping-room.
7. Material shipped.
8. Correspondence in regard to order.

In case it is desired to record more than eight stages of progress, as may be required in complicated kinds of work, other elements of the square than its diameters may be used. Eight more phases can be added by marking along the halves of the vertical and horizontal sides of the square.

The principal advantages which this method of charting affords are the following:

1. The whole history of the action on a given piece of work is recorded permanently.

2. The total interval required for the work is suggested at once by the distance between the initial and final lines drawn, so that the efficiencies or adequacies of the organizations of the several departments can be directly compared.

3. Instant and reliable answers can be given by the central office to inquiries received by mail or telephone.

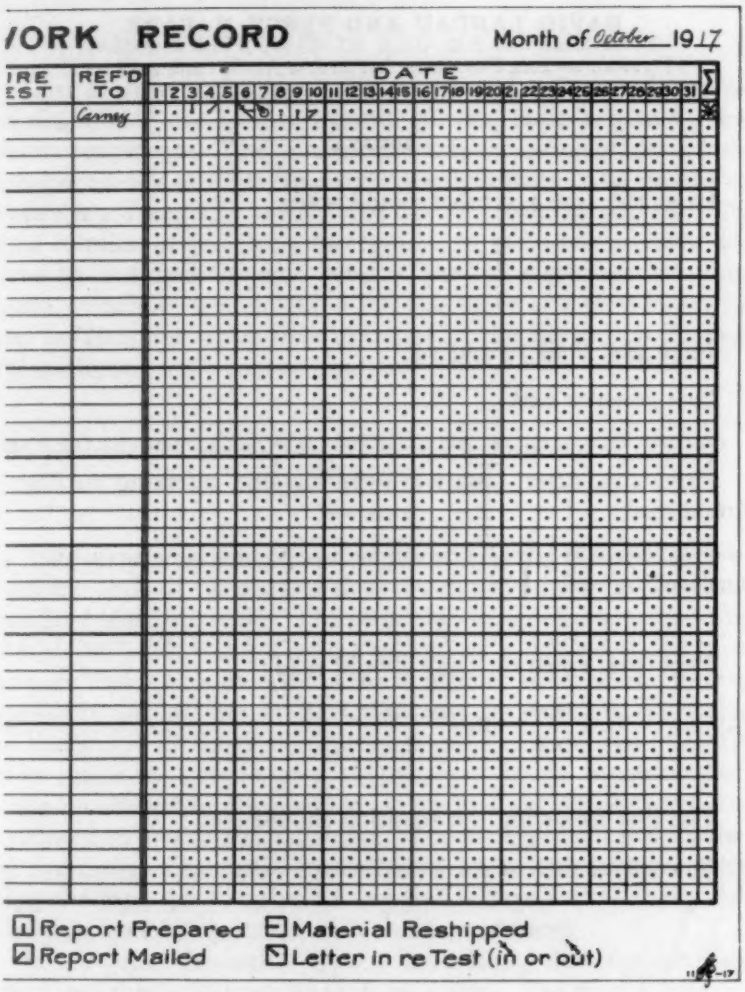
4. Work which is not completed in proper time is readily noticed by reference to the summation column, headed Σ, so that necessary corrective action can be taken.

The principal advantages of this chart over the usual progress-of-work board are in the permanency of the record, which is not lost by the moving of a pin or block to the next position; its compactness; and, finally, the greater detail and definiteness of the information which it affords, making its use available to administrative officers and office employees, as well as to the foremen and department heads immediately in contact with the work.

PROGRESS-OF-W

TEST NO.	MATERIAL	REQUESTED BY	NATU OF TE
981	2 airplane control wires	Jones Aircraft Co	tensile

U Request Dated E Material Received
R Request Received T Test Begun


/ORK RECORD
Month of October 1917
IRE EST
REF'D TO
DATE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Σ
Carney
Report Prepared
Report Mailed
Material Reshipped
Letter in re Test (in or out)

A NEW THEORY OF PLATE SPRINGS.

BY

DAVID LANDAU AND PERCY H. PARR.

(JOURNAL OF THE FRANKLIN INSTITUTE, April, 1918, page 481.)

ERRATA.

Page 488, line 4, symbol should read:

$$\frac{1}{2}\, l_2$$

Page 488, lines 12 and 13:

Omit quotation marks.

Page 493, after equation (1), the line referring to Fig. 7 should read:

Now, referring to Fig. 7, it will be seen that for the n + 1th plate, we must have, for

Page 494, equation (5a) should read:

$$EI_{n+1}\delta_{n+1} = W_{n+1}\frac{P_{n+1}}{3} - W_n\left(\frac{P_n l_{n+1}}{2} - \frac{P_n}{6}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5a)$$

The line following the equation should read:

Now putting n for $n + 1$ in (5a) there results:

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

RADIO INSTRUMENTS AND MEASUREMENTS.

THE Bureau of Standards has issued a treatise on radio measurements,[1] for use by government officers, radio engineers, and others concerned. The circular includes a development of the essential theory of high-frequency measurements from simple but precise low-frequency theory, the use of reactance curves in the rapid solution of problems, descriptions of radio instruments, and formulas and data for radio work. The full treatment of fundamental principles will make this circular serve as a foundation for later publications which may be issued by the Bureau on the general subject of radio communication.

STABILIZED-PLATFORM WEIGHING SCALE OF NOVEL DESIGN.[2]

[ABSTRACT.]

THIS paper treats of the principles and design of a new type of weighing scale of the general class technically known as the check stabilized-platform scale. The usual stabilizing element consisting of a pin-and-link connection is replaced by a flexible elastic tape, band, or wire. This design has the important effect of eliminating practically all of the friction inherent in existing stabilizing mechanisms, with the result that the friction of stabilized-platform scales made in accordance with this new design becomes practically unaffected by the position of the load on the platform and is reduced to a very small amount. The arrangement is such that the stabilizing element is continuously under tensile stress; this being the case, the function of that link is then satisfactorily fulfilled by a flexible connector, such as a tape or band.

In the paper the earlier types of stabilizing elements are illustrated and the limitations of each set forth. The theoretical considerations underlying the conditions of equilibrium in weighing

* Communicated by the Director.

[1] Circular No. 74.

[2] Technologic Paper No. 106.

scales of the stabilized-platform type are defined and the methods used in carrying out the adjustment of such a scale are outlined. A discussion of the effects of static friction on the indications of scales is included, and the effect of the elimination of this friction in enhancing the accuracy of weighing is shown. The paper includes nearly a score of illustrations of weighing scales and scale details.

RESONANCE AND IONIZATION POTENTIALS FOR ELECTRONS IN CADMIUM VAPOR.[3]

[ABSTRACT.]

THE object of this investigation has been the determination of the resonance and ionization potentials for electrons in cadmium vapor. Resonance collision of the electron with the atom was observed at 3.88 volts, and inelastic impact resulting in ionization was observed at 8.92 volts. The single line spectrum of cadmium is $\lambda = 3260.17$ Å. If we substitute the frequency corresponding to this wave-length in the relation $h\nu = eV$ where $h = 6.56.10^{-27}$ erg.-sec., e the electronic charge, and V the resonance potential, we obtain $V = 3.79$ volts, in good agreement with the above. On the basis of Bohr's theory, the ionization potential should be 8.97, in most excellent agreement with the experimentally determined value.

THE APPLICATION OF DICYANIN TO STELLAR SPECTROSCOPY.[4]

[ABSTRACT.]

THE Bureau of Standards has had considerable success in photographing extreme red and infra-red radiations by means of commercial plates sensitized with dicyanin. This article describes the application of such plates to stellar spectroscopy. The observations were carried out at the Harvard College Observatory, using the 24-inch reflecting telescope and objective prism. Fraunhofer's A band (wave-length 0.760μ) and a considerable region of greater wave-length were photographed in numerous stellar spectra. Several new absorption flutings were discovered, the most striking beginning at 0.760μ, nearly coincident with A, and

[3] Scientific Paper No. 317.
[4] Scientific Paper No. 318.

running toward the red. Circumstances indicated that this band might be due to titanium oxide, and experiments since made at the Bureau of Standards have shown a band in this position in the spectrum of the titanium arc. The greatest wave-lengths observed in stellar spectra appear, by extrapolation, to be about 0.87μ. The general conclusions arrived at are as follows:

1. Many stellar spectra possess sufficient intensity in the region of wave-length 0.80μ to enable this portion of the spectrum to be photographed on plates sensitized with dicyanin.

2. In favorable instances stellar spectra can be well observed to wave-length 0.85μ.

3. The region of greater wave-length than 0.70μ contains features of importance, especially in the case of the later spectral types.

A Single-lens Telescope. ANON. (*The Optical Journal and Review*, vol. 41, No. 13, p. 868, March 21, 1918.)—The first telescope invented, several hundred years ago, consisted of two lenses, a convex lens for the objective and a minus lens for the eye-piece. We still have this form of telescope in use, but it is now made binocular; that is, the ordinary opera-glass or field-glass. The magnifying power of such an instrument would be the same if it consisted of one tube and not two. In fact, we can take two lenses from a trial case, one plus the other minus, and hold them at the proper distance so as to have a telescope in its simplest form. When the eye of the observer is hypermetropic it is possible to obtain a magnifying effect similar to that produced by a telescope, by means of a single lens.

The eye of a person, hypermetropic (farsighted) 1.50 D. (diopters), will be optically similar to that of an emmetrope (person with normal vision) wearing a minus 1.50 D. sphere. Therefore, if we select a suitable plus sphere and hold it out at the right distance in front of the uncorrected eye there should be a magnifying effect, and there is. Should a plus 0.75 D. sphere be used in this way, and held at a distance of 26 inches from the eye, there will be magnification of two times. If the hypermetropia is higher than 1.50 D., the magnification will be higher; also, if the low-power plus lens used as an objective is hung up in some convenient manner, a lower power can be used, the observer takes his position farther away, and there will be a greater magnification. Some years ago an amateur yachtsman, who had a hypermetropic error of 2 D., hung a large lens of low power in his club window, and then, by taking a comfortable position a few feet back of the lens, he could see the boats sailing by under a magnification of three or four diameters, and in perfect focus.

Nature of "Rice Polish." ANON. (*Weekly Bulletin Trade and Technical Press Section,* U. S. Food Administration, vol. 1, No. 31, p. 5, March 23, 1918).—"Rice polish" is a comparatively new cereal substitute, being the waste which comes from the rice in the polishing process whereby the outer layers of the grain, containing phosphorus, are removed. Formerly this rice polish was sold by the ton for stock food, but Miss Rona K. Armstrong, of the United States Department of Agriculture, visiting New Orleans, discovered it and had it placed on the market for making conservation bread in proportions of one-fourth rice polish to three-fourths wheat flour. The *Flour and Grain World* describes methods of cleaning and polishing rice whereby this product is obtained. Rough rice from the thrashing machine is first separated from thrash, the hulls or chaff removed by rapidly revolving millstones, and the outer skin of the grain then removed by pounding in huge mortars, which gives a mixture of clean rice, fine chaff, and flour. The rice is then polished by friction against moose hide or sheepskin, tanned and worked to a high degree of softness, where the outer layers of the grain are moved, yielding rice polish, which is said to contain the most nutritive portions of the grain.

Effect of Artificial Light on the Growth and Ripening of Plants. J. L. R. HAYDEN and C. P. STEINMETZ. (*General Electric Review,* vol. 21, No. 3, p. 232, March, 1918.)—Of the thousand-and-one uses of the electric light, one of the most unique is its application to stimulate plant growth and fruition. To determine how much the growth and ripening of plants is thus stimulated, an investigation was conducted on the growth of beans in a greenhouse under electric illumination as compared with their development under natural light. The investigation was made on beans, as the natural life of the bean plant is relatively short, and it was therefore possible to get results in a reasonably short time. Gas-filled Mazda lamps were used, as previous experiments in Doctor Steinmetz's laboratory had shown that the quality of light from this type of lamp is very efficient in its action on plant growth.

A piece of ground 5 feet by 9 feet, having good black soil, was illuminated by five 500-watt lamps consuming 2.5 kilowatts. As a check test, the same kind of beans were planted in a box 36 inches square, with the same soil, under natural light. Under the influence of intense artificial illumination the fruit ripened in a little more than half the time required under daylight alone, and the saving in time is about equal to that during which the intense illumination is maintained. Although it is not profitable to raise such relatively cheap products as string beans by artificial light, such use of light for raising plants may be justified where the electric current is generated as a by-product of the heating plant, but at the cost of purchased power it would be economically justified only for temporary use with plants which have a market value only at a definite time.

NOTES FROM NELA RESEARCH LABORATORY.*

ATOMIC HEATS OF TUNGSTEN AND OF CARBON AT INCANDESCENT TEMPERATURES.

By A. G. Worthing.

Of late years great interest has been manifested in the question of atomic heats, particularly at very low temperatures, because of the great success of theories based on the quantum hypothesis in explaining quantitatively the variations which have been found. These theories generally tend toward a value of 5.95 $\frac{\text{calories}}{\text{gram-atom degree}}$ as the upper limiting value for the atomic heat of a solid under the condition of constant volume. Several substances, however, have been shown to possess greater atomic heats even at temperatures ranging from room temperature up to 700° C. or 800° C. Modifications of theory have been offered to explain these excess values, but none that are quantitative in character. Tungsten, as a material which reaches the 5.95 $\frac{\text{calories}}{\text{gram-atom degree}}$ value at ordinary temperatures, offers exceptionally favorable opportunities for the investigation of these characteristics at high temperatures.

In the present investigation the materials investigated have been in the form of uniform filaments mounted in evacuated bulbs. Due regard being paid to end losses, we have the following operating condition for a uniformly heated filament

$$IV = f(T) + C_p m \frac{dT}{dt},$$

in which I represents current, V voltage, T temperature, C_p specific heat, m mass, and t time. The equation states that the rate of supply of energy to the filament is equal to the sum of the rate of radiation of energy by the filament and the rate of storing up of energy in the filament. Evidently the equation applies to a cooling as well as to a heating change.

For convenience the above equation may be rewritten as

$$IV = F(R) + C_p m \frac{dT}{dR}\frac{dR}{dt}$$

in which R represents resistance. This assumes that, during

* Communicated by the Director.

changes of temperature, the temperature and the rate of radiation are single valued functions of the resistance. Granted this assumption, the experimental work consists mainly in determining I and V as function of t for certain definite temperature changes. This has been done with the aid of a pendulum apparatus and a potentiometer outfit, using the successive trial method. As the pendulum swung from its initial position, it operated switches which first changed the resistance in the circuit containing the filament and then, after a fixed interval, closed momentarily a galvanometer circuit showing the correctness or deviation therefrom of the potentiometer setting for the voltage or current. Successive determinations for various intervals gave I and V as functions of t. From these there follows R as a function of t. $F(T)$ represents steady state wattages. T as a function of R follows from temperature calibrations.

For tungsten the results by the cooling method show certain deviations from those obtained using the heating method. This seems to indicate that the assumption of the temperature and wattage being single valued functions of the resistance is not fulfilled. This is not considered definitely proved, however. Taking the results as a whole, the atomic heats under constant volume are fairly well represented by a straight-line relation consistent with 6.25 $\frac{\text{calories}}{\text{gram-atom degree}}$ at 1200° K and 7.35 $\frac{\text{calories}}{\text{gram-atom degree}}$ at 2400° K. These are considerably in excess of the supposed limiting value 5.95 $\frac{\text{calories}}{\text{gram-atom degree}}$. Suggestions which have been advanced in explanation of this fact, when considered quantitatively and theoretically, are not found satisfactory.

The results for carbon were not as carefully obtained. They show an approximate linear relationship consistent with 5.35 $\frac{\text{calories}}{\text{gram-atom degree}}$ at 1200° K. and 6.05 $\frac{\text{calories}}{\text{gram-atom degree}}$ at 2000° K. for the atomic heat under constant pressure. When corrections are made to the condition of constant volume, these results will possibly be in accord with 5.95 $\frac{\text{calories}}{\text{gram-atom degree}}$ as an upper limit. As they stand they are in very good agreement with Weber's results on diamond and graphite at ordinary temperatures and of Magnus's conclusions regarding Weber's data on the same materials at higher temperatures.

THE VISIBILITY OF RADIATION IN THE BLUE END OF THE SPECTRUM.

By L. W. Hartman.

THE determination of the visibility of radiation in the short wave-length region of the spectrum is difficult, owing principally to the small amount of light available when using ordinary methods and sources. The optical pyrometer method, which had previously been employed [1] in obtaining this function for the red end of the spectrum, minimizes this difficulty, and has now been used to obtain values of the visibility in the blue end out as far as wave-length 0.400μ. In contrast to results obtained by the flicker photometer, this method involves the direct-comparison principle.

The effect of stray light and of extreme color-difference was eliminated to a very large extent by the use of a piece of blue glass, of known spectral transmission, in the eyepiece of the telescope. During any one run the brightness was kept constant, but experiments were also made with values of brightnesses as seen through the blue glass ranging from 0.000033 to 0.0013 candle per square centimetre. A small field was employed, and tests indicated no evidence of a Purkinjé effect. Corrections were made for slit-widths, for the dispersion and selective absorption of the prism and lens system, for scattered light, and for the absorption of the blue glass.

Measurements were made by twenty observers, all of whom were trained in laboratory work. The results, together with the published data of other investigations are given in the table.

Wave-lengths, $\mu\mu$	Mean visibility of twenty subjects	Mean values given by Nutting*	Mean values given by Coblenz and Emerson
410	1.7	9.5	24
420	11.4	17.1	42
430	32.6	30.3	59
440	61.6	58.0	71
450	100	100	100
460	153	168	137
470	240	266	202
480	376	392	305
490	620	566	474
500	905	828	770

*These values, kindly furnished by Doctor Nutting, differ slightly from his published data, owing to the redetermination of the distribution of energy in the spectrum of the acetylene flame used.

[1] *Astrophys. Jour.*, vol. 42, 1915, p. 285.

EFFECT OF HYDROGEN ON THE ELECTRICAL RESISTIVITY OF CARBON.

By T. Peczalski.

THE effect of hydrogen on the electrical resistivity of carbon has been studied at different temperatures and pressures. It has been found:

1. That hydrogen apparently produces no effect on the resistivity at ordinary temperatures for pressures up to 33 atmospheres.

2. That the resistance of carbon increases considerably when the filament is heated to a high temperature in hydrogen.

3. That the resistance at room temperatures following such a heating in hydrogen shows a similar and more marked increase.

4. That subsequent heating of the filament in vacuum to the same temperature produces the opposite effects.

5. That the effect is greater for the higher pressures than for the lower pressures.

6. That these changes are suggestive of an exponential law and are about equal in magnitude in cases where the filaments are not injured appreciably by the processes involved.

The Doretype—a De Luxe Style of Portrait Photograph. ANON. (*The British Journal of Photography*, vol. 65, No. 3009, p. 4, January 4, 1918.)—A new style of portrait photograph, the Doretype, has recently been introduced through the Eastman School of Professional Photography, as a means of providing a form of portrait photograph of rich distinctive appearance, yet capable of being produced at a comparatively low cost. The Doretype is a warm-toned, thin, positive image on glass, and receives its brilliancy from the material which is used as a backing. It lends itself to almost any treatment. It may be backed with light-tinted papers, or various shades of fine silk or satin, but the most satisfactory method is to coat the back of the transparency with a fine gold bronze.

With edges simply bound or the picture mounted in a frame, most of the attractiveness of the Doretype is lost. The aim of the promoters has evidently been to originate something which in its way can be prized by the possessor just as the daguerreotype miniatures were prized in their day. The new process is not one that can be entrusted to an indifferently skilled operative, but calls for a high degree of skill in the making of the glass transparency, and, like the daguerreotype, needs a fitting setting to show it to the best advantage.

NOTES FROM THE RESEARCH LABORATORY. EASTMAN KODAK COMPANY.*

THE VISIBILITY OF RADIATION.[1]

By Prentice Reeves.

[ABSTRACT.]

THIS experiment was performed to obtain more data on the subject by using a method similar to that used by Ives [2] and Nutting.[3] The values for the spectral energy distribution of acetylene were those offered by Nutting and two values offered by Coblentz. The data obtained by using the different acetylene energy values enable one to compare results with the other experiments, as well as to show the effect of using the values with the same data.

The apparatus used was a modification of the Nutting monochromatic colorimeter. The light from a standard acetylene burner passes through a pair of Nicol prisms and a collimating lens to a constant deviation dispersing prism which is operated by a screw carrying a direct-reading wave-length drum and then to the observer's eye. By means of a Whitman disk the light from a gas-filled tungsten lamp which passes through a daylight filter is intermittently mixed with the monochromatic light, and a flicker balance is made by varying the intensity of the colored light. With both light-sources constant and three independent series taken on different days it is safe to assume that the resultant average for each of the thirteen observers is representative.

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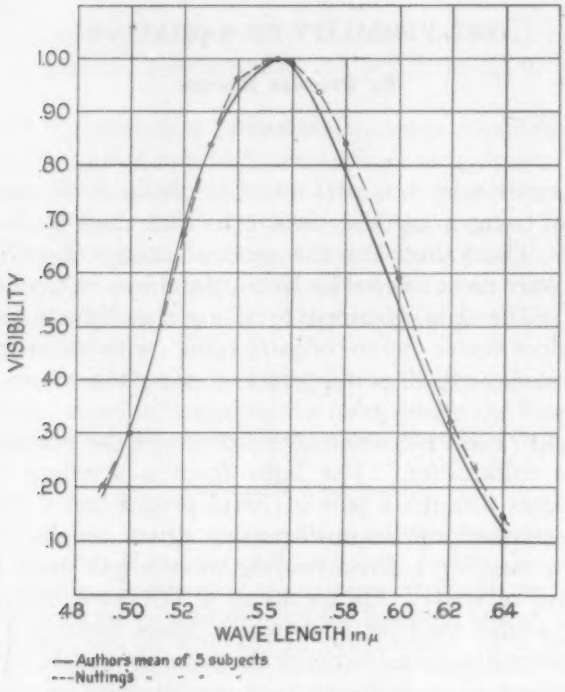
* Communicated by the Director.

[1] Communication No. 55 from the Research Laboratory of the Eastman Kodak Company, published in *Trans. Illuminating Engineering Society*, February, 1918, p. 101.

[2] H. E. Ives, *Phil. Mag.*, 1912, **24**, p. 149.

[3] P. G. Nutting, *Phil. Mag.*, 1915, **29**, p. 301; *Trans. Illum. Eng. Soc.*, 1914, **9**, p. 633.

Five of the observers in the experiment were also observers in Nutting's experiment, and the figure shows the mean of the writer's results and Nutting's results from these five observers treated separately. For these observers the average maximum visibility found by the writer is 0.555 and by Nutting 0.554.



The table shows the writer's data obtained from all observers when using the different acetylene results, the means obtained by Nutting and Ives, and visibility as computed from Nutting's formula

$$V = Vm\, R^{a}\, e^{a\,(1-R)}$$

where $R = \lambda$ max 1λ and $a = 181$. The maximum visibility obtained from the thirteen observers is at wave-length 0.553 in agreement with Ives, as against 0.555 from Nutting's results.

TABLE OF COMPARATIVE VISIBILITY RESULTS.

Wave-length	Mean V from 13 subjects	Coblentz data pub. 1911	Coblentz data pub. 1916	Nutting's mean	Ives's mean	Computed from formula
0.49	0.175	0.172	0.172	0.237	0.235	0.232
0.50	0.289	0.283	0.275	0.330	0.363	0.358
0.51	0.475	0.471	0.474	0.477	0.596	0.514
0.52	0.702	0.705	0.686	0.671	0.794	0.675
0.53	0.842	0.851	0.841	0.835	0.912	0.824
0.54	0.950	0.947	0.935	0.944	0.977	0.933
0.55	0.990	0.988	0.993	0.995	1.000	0.994
0.56	0.977	0.982	0.985	0.993	0.990	0.993
0.57	0.898	0.926	0.935	0.944	0.948	0.939
0.58	0.807	0.825	0.836	0.851	0.875	0.839
0.59	0.676	0.693	0 710	0.735	0.763	0.717
0.60	0.548	0.552	0.580	0.605	0.635	0.585
0.61	0.409	0.417	0.446	0.468	0.509	0.456
0.62	0.293	0.294	0.319	0.342	0.387	0.343
0.63	0.194	0.185	0.214	0.247	0.272	0.235
0.64	0.127	0.125	0.140	0.163	0.175	0.158

Degrees of Permanence in Photographic Prints. ANON. (*The British Journal of Photography*, vol. 65, No. 3015, February 15, 1918.)—Within ten or fifteen years ago a photograph by a "permanent" process meant one by either the platinum or carbon process. There is a very good reason why it had this signification, for during the twenty-five or thirty years during which albuminized paper was the printing method in universal use carbon and platinum prints were the only two forms of photograph which could be said to have established themselves as yielding prints of unquestioned permanence, and in this respect were distinguished from the ordinary silver prints, with their liability, particularly in later years, to fade. Opinions will differ as to what constitutes permanence, but such a formula is that no marked alteration will be observable in prints when kept under reasonable conditions for a period of, say, twenty years. This definition refers to prints belonging to the vast majority classed as portraits, views, etc. Obviously twenty years would be much too short a time for prints in which permanence is a prime consideration; such prints would be expected to last for fifty or a hundred years. Leaving carbon and platinum out of consideration, there can be no doubt that the most permanent form of photograph among the papers available at the present time is that on a bromide or gaslight paper. Such a print, if properly made and mounted, and preserved under suitable conditions, should meet the permanence requirement of twenty years' life. The effect of time upon it when mounted and framed should never be more than a slight yellowing of the whites, and need not necessarily be that.

Nomography. F. L. MARTINEAU and A. M. ARTER. (*Proceedings of the Institution of Automobile Engineers,* March, 1918.)—There is probably no device of mathematical analysis that has proved so great an aid to progress in every branch of technology as the graphic diagram in rectangular coördinates. Although other methods of graphically representing functions and variables have been developed, for the majority of applications the rectangular system, as may be judged by its widespread use, has proved preferable. Works on analytic geometry are generally restricted to a discussion of the rectangular and the extensively though less used polar systems. Among other methods of graphically representing variable quantities that have been developed in recent years, the system known variously as "nomography," "alignment charts," and "parallel coordinates" has come into use, and is proving an important labor-saving device in graphic calculations better adapted to the purpose than the coördinate diagram.

This system is based upon the use of parallel axes upon which values of the variables are graduated. A simple form of a chart of this kind is represented by thermometer scales with adjacent graduations in Centigrade and Fahrenheit. With three variables there are three separate parallel lines. From these the required value of the function is determined by the intersection of a transversal passing through the two known values of the variables marked on the adjacent parallels. Under certain conditions one and sometimes all of these lines become curved. The advantage of the nomographic diagram is apparent when a two-variable equation with a variable parameter is considered. With the rectangular system a series of curves must be constructed for different values of the parameter, and interpolations with such a diagram are uncertain. The nomogram, on the other hand, consists of only three graduated lines from which values are easily read or interpolated.

The system was first introduced by M. d'Ocagne, of the École Polytechnique, in Paris, in or about the year 1884. For a study of the subject the following works may be consulted: "Alinement Charts," E. S. Andrews, 1917; "Graphs and Abacuses," R. de Beaurepaire, Madras, 1907; "The Use of Nomograms in the Determination of Thermal Efficiency of Internal-combustion Engines," W. J. Goudie, *Proceedings Inst. Engineers and Shipbuilders in Scotland,* 1916–17; "Nomography, or the Graphic Representation of Formulæ," Royal Artillery Institution, 1913; "Traité de Nomographie," M. d'Ocagne, Paris, 1899; "Calcul Graphique et Nomographie," M. d'Ocagne, Paris, 1914 (the latter work contains a complete bibliography of French works on the subject); "The Construction of Graphical Charts," John B. Peddle, New York, 1910; "Graphical Methods," C. Runge, New York, 1912.

THE FRANKLIN INSTITUTE.

(*Proceedings of the Stated Meeting held Wednesday, April 17, 1918.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 17, 1918.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 2.

Reports of progress were presented by the Committee on Science and the Arts and the Committee on Library.

The Chairman then introduced Lieut.-Col. Allerton S. Cushman, Ph.D., Ordnance Department, N. A., formerly Director of the Institute of Industrial Research, Washington, D. C., who presented a communication, entitled "Growing of Medicinal Plants in America." The speaker referred to such plants as stramonium, belladonna, aconite, digitalis, etc., from which substances used as medicines are extracted. Prior to the present war the medicinal herbs were imported from European or Asiatic countries, many of them controlled by the Central Powers. The higher cost of labor in the United States had not made it possible to undertake the large-scale production of these as regular crops. The speaker and his associates have since attempted the production of temperate-zone medicinal plants, especially belladonna, with a view to meeting the demand of our home markets. It was found necessary in this undertaking to devise some special forms of machinery for planting and other purposes, and these were fully described. The various steps in the care and handling of the plants, from the seeds to the final transplanting in the open field, were outlined as well as the steps taken to protect them against insects and other destructive agents.

A moving picture of the propagation and care of some of these medicinal plants was shown.

After a brief discussion, the thanks of the meeting were extended to Colonel Cushman.

Adjourned.

GEORGE A. HOADLEY,
Acting Secretary.

MEMBERS OF THE FRANKLIN INSTITUTE WHO ARE IN THE ACTIVE MILITARY OR NAVAL SERVICE OF THE UNITED STATES GOVERNMENT.

Name and rank	Branch of service	Location
Abbott, A. C., Lieut.-Col.	Greenleaf School of Military Hygiene	Chickamauga Park, Ga.
Allen, Henry B., 1st Lieut.	Ordnance Dept., U. S. R.	France
Anderson, Geo. L., Colonel	Board of Ordnance & Fortification	Washington
Atherholt, Gordon Meade	Aeronautical Mechanical Engineer, Signal Corps	Washington
Atterbury, W. W., Brig. Gen.	Director-General of Railways	France
Bacon, Raymond Foss, Lt. Col.	Head of Chemical Service Section, U.S.N.A.	France
Barnhart, G. Edw.	Aeronautical Mechanical Engineer, Signal Corps	Fairfield, Ohio
Barr, John H., Major	Ordnance Reserve Corps	Washington
Barrett, C. D., Major	9th Engineers	
Bartow, Edward, Major	U.S.N.A. Sanitary Corps	France
Booz, Horace Corey, Colonel	Railroad Transportation Corps, U.S.N.A.	France
Bostwick, John Vaughan, Capt.	O.R.C., 315th Infantry	Camp Meade
Breed, George, Lieutenant	Fleet Naval Reserve, U.S.N. R.F.	New York
Bunting, C. M., Colonel	E.O.R.C., U.S.A.	France
Cadwalader, Governeur, Major	Ordnance Dept., U.S.R.	
Caldwell, E. W.	Medical Officers' Reserve Corps	
Capps, W. L., Rear Admiral	Chief Constructor, U.S.N., Bureau of Construction and Repair	Washington
Carty, John J., Colonel	Signal Corps, U.S.A.	
Chance, Edwin M., Capt.	Ordnance Dept., U.S.R.	Washington
Clark, Beauvais, Sergeant	108th Field Artillery	Camp Hancock
Clark, E. L., 1st Lieut.	Signal Corps, 401st Telegraph Battalion	Camp Devens
Clark, Theobald F., Capt.	Field Artillery	Fort Sill
Clark, Walton, Jr., Capt.	Field Artillery	Fort Sill
Cornelius, John C., 1st Lieut.	Coast Artillery, U.S.N.A., 13th Company	Sandy Hook
Cottrell, Jas. W., Private	Instruction Section, Ordnance Dept., U.S.A.	Peoria, Ill.
Cowan, Henry B., Sergeant, 1st Class	Co. D., First Telegraph Battalion, Signal Reserve Corps	France
Crampton, George S., Major	Director of Field Hospitals, 28th Div.	Camp Hancock
Cushman, A. S., Lieut. Col.	Ordnance Dept., U.S.N.A.	Frankford Arsenal
Detwiler, Jas. G., 1st Lieut.	Infantry, U.S.R.	Fort Logan H. Roots
Eckert, S. B., Lieut.	Commander 9th Aero Squadron	France
Elliott, Henry M., 1st Lieut.	Ordnance Dept., U.S.R.	Western Cartridge Co.
Emerson, Geo. H., Colonel	In charge of Russian Railway Service Corps	Japan
Felton, Samuel M.	U. S. Director-General of Railways in connection with Expeditionary Force	Chicago

Name and rank	Branch of service	Location
Ferguson, Walter B., Private	21st Co., 154th Depot Brigade	Camp Meade
Fraser, Persifor, Ensign	U.S.N.R.F.	League Island
Gardner, H. A., Senior Lieut.	Naval Flying Corps	Washington
Gfrörer, A. H., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Gibbons, Joseph E., Private	Co. D., 103rd Engineers	Camp Hancock
Gillmor, R. E., Senior Lieut.	U. S. Navy	New York
Glendinning, Robt. E., Major	Aviation Section, Signal Corps	Overseas
Goodwin, Harold, Jr., Lieut.	Naval Reserve Force	Philadelphia
Gribbel, W. G., Captain	Co. A., 30th Engineers, U.S.R. (Gas and Flame)	France
Griest, Thos. S., 1st Lieut.	1st Telegraph Battalion, Signal Corps, U.S.A.	France
Hall, R. T., Rear Admiral	U. S. Navy, Inspector of Machinery	Cramps' Shipyard
Hodges, Austin L., Capt.	Ordnance Dept., U.S.R., Experimental Officer on Artillery Ammunition	Frankford Arsenal
Howson, Richard, Sergeant	306th Ambulance Corps	Camp Meade
Ives, H. E., Captain	Signal Corps, U.S.A.	Washington
Jones, Jonathan, Captain	E.O.R.C., 23rd Engineers	Camp Laurel
Karrer, Enoch, Private	45th Engineers, Company A	Camp Meade
Kennedy, M. C., Colonel	Deputy Director General of Transportation	France
Kent, S. Leonard, Jr., 2nd Lieut.	5th Engineers	Camp Lee
Kingsbury, E. F., 1st Lieut.	Aviation Section, S.O.R.C., Dept. of Science and Research	Washington
LeBoutillier, H. W., Private	Unit No. 10, Pennsylvania Hospital	France
Lichtenberg, Chester, 1st Lieut.	Engineer Reserve Corps, U.S.A.	Washington
Longstreth, Chas., Lt. Commander	U.S.N.R.F.	Philadelphia
McCoy, John F.	Aviation Section, Signal Corps	Princeton
MacLean, Malcolm R., Major	Infantry R. C.	Camp Meade
McMeekin, C. W., Major	Army War College	Washington
Martin, Thos. S., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Masters, Frank M., Major	Ordnance Dept., U.S.R.	Washington
Maxfield, H. H., Lieut. Col.	19th Railway Engineers, U.S.N.A.	
Mershon, Ralph D., Major	E.O.R.C., U.S.A.	New York
Miller, Fred. J., Major	Ordnance Reserve Corps	Centre Bridge, Penna.
Owens, R. B., Major	Signal Corps	France
Parrish, T. R., 1st Lieut.	Signal Corps	Washington
Reber, Samuel, Colonel	Signal Corps, U.S.A.	New York
Richardson, Chas. E., 1st Lieut.	30th Engineers, U.S.R. (Gas and Flame)	France
Spackman, Henry S., Major	Engineer Officers' Reserve Corps	France
Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase, Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
Stanford, H. R., Civil Engineer	U. S. Navy	Boston
Thomas, Geo. C., Jr., Captain	Aero Service Squadron 96, Aviation Section, Signal Corps	France
Tilghman, B. C., Captain	A.D.C., 28th Div. Headquarters, U.S.A.	
Vogleson, J. A., Major	Camp Jas. E. Johnston	Jacksonville, Fla.
Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington

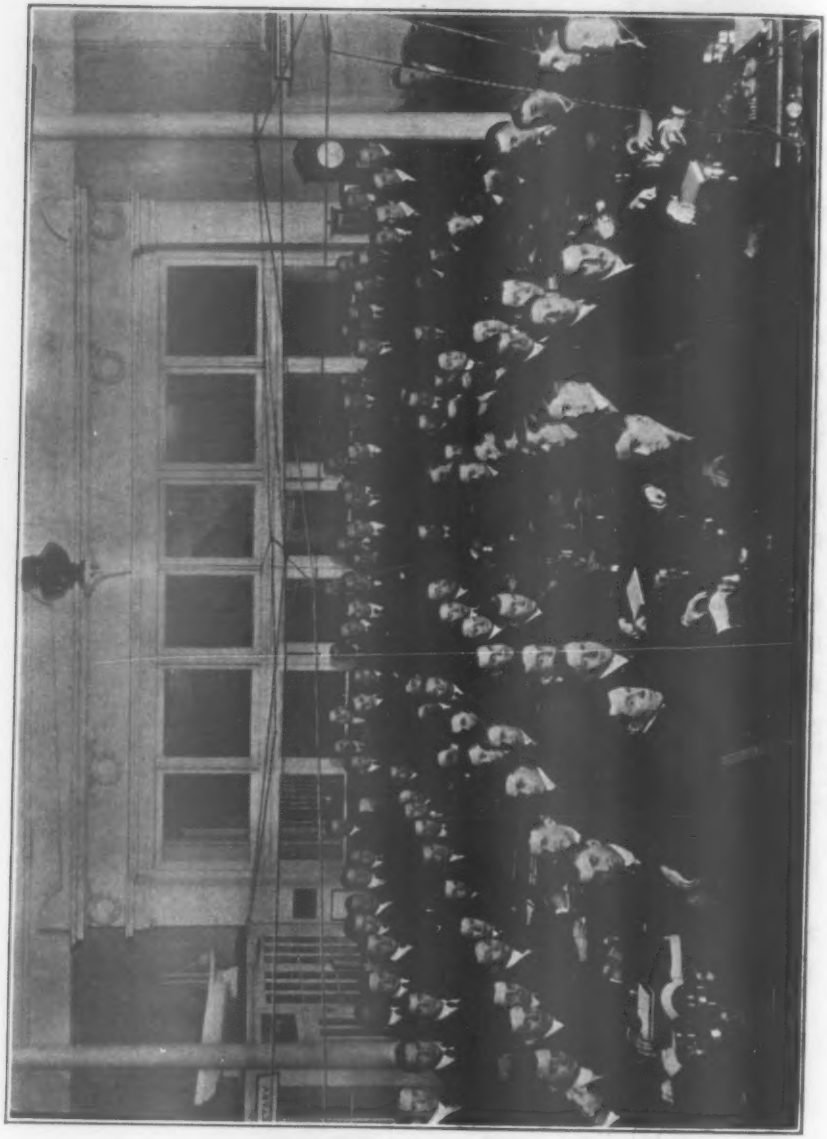
Name and rank	Branch of service	Location
Wagner, Fred. H., Jr. Sergeant	Co. E., 304th Engineers	Camp Meade
Wetherill, W. C., Ensign	U. S. Navy	
Widdicombe, R. A., Major	C.Q.M., Chemical Plant No. 4	Saltville, Va.
Wood, Edw. R., Jr., Captain	18th Field Artillery, U.S.N.A.	El Paso, Texas
Worrell, Howard Sellers	3rd Officers' Training Camp	Fortress Monroe
Wyckoff, A. B., Lieut.	U. S. Navy	Ontario, Cal.
Yale, A. W. Major	Medical Reserve Corps, Gas Division	Camp Kearney
Yorke, George M., Major	Signal Corps, U.S.R.	New York

MEMBERS DOING CIVILIAN WORK FOR THE UNITED STATES GOVERNMENT

Name	Appointment	Location
Akeley, Carl E.	Consulting Expert of Mechanical Devices, War Department	Washington
Anderson, Robt. J.	Engineer of Tests of Ordnance, War Dept., U.S.A.	Brier Hill Steel Co.
Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept. (Gas Warfare, Shells, etc.)	New York
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia
Brown, Lucius P.	Federal Milk Commission	New York
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
Charles, Bernard S.	Ordnance Inspector, U. S. Navy	Allentown, Pa.
Comey, Arthur M.	Chairman, Sub-Committee on Explosives, Chemistry Committee, National Research Council	Chester, Pa.
Condict, G. Herbert	Naval Consulting Board, Member Committee of Examiners	Plainfield, N. J.
Cooke, Morris L.	Chairman, Storage Committee of Munitions Board; Member on Staff, Emergency Fleet Corporation	Washington
Cope, Thomas D.	National Research Council	Washington
Day, Charles	Member of Army War Council	Washington
Delano, Frederic A.	Member of Federal Reserve Board	Washington
Dickie, G. W.	Chief Inspector, U. S. Shipping Board, Moore & Scott Shipyard	Oakland, Calif.
Dunn, Gano	Chairman, Engineering Committee, National Research Council	New York
Garrison, Frank Lynwood	Chairman, U. S. Manganese Commission	Philadelphia
Halberstadt, Baird	Federal Fuel Administrator for Schuylkill Co., Penna.	Pottsville
Hoskins, Wm.	Consulting Chemist, Advisory Committee, Bureau of Mines; Associate Member, Naval Consulting Board	Chicago

Name	Appointment	Location
Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman).	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ.
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Lucke, C. E.	Civilian Director, U. S. Navy Gas Engine School	Columbia Univ.
Merrick, J. Hartley	Director, Bureau of Camp Service, Penna. Div., American Red Cross	Philadelphia
Milne, David	Treasurer, American Red Cross General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll, B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia
Rapp, Isaiah M.	Special Investigator of Weights and Measures for the U. S. Food Administration	Norman, Oklahoma
Rautenstrauch, Walter	Committee of the National Research Council	New York
Richards, Joseph W.	Member of Naval Consulting Board	So. Bethlehem, Penna.
Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Stern, Max J.	Supervising Surgeon, Merchant Shipbuilding Corporation	Philadelphia
Stradling, George F.	Recruiting for Aviation Section, S.O.R.C.	Philadelphia
Swenson Magnus	Federal Food Administrator for Wisconsin; Chairman, State Council for Defense	Madison, Wis.
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.

Please send additional information and corrections to the Secretary.



RADIO SCHOOL OF THE FRANKLIN INSTITUTE

IN COÖPERATION WITH THE FEDERAL BOARD FOR VOCATIONAL EDUCATION.

Fifty-four of the students completed the required course, passed the necessary tests, and were inducted into the service of the army on April first.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, April 3, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 3, 1918.

DR. H. JERMAIN CREIGHTON *in the Chair.*

The following report was presented for first reading:

No. 2708.—The Waterbury Hydraulic Speed Gear.

The following report was presented for final action:

No. 2709.—The Fahy Permeameter. Frank P. Fahy, of New York City, N. Y., recommended to the City of Philadelphia for the John Scott Legacy Medal and Premium.

On the recommendation of the Sub-Committee on Literature, the following awards were made for papers in the JOURNAL, 1917:

No. 2718.—The Howard N. Potts Medal to Dr. Alexander Gray, of Ithaca, N. Y., for his paper, entitled "Modern Dynamo Electric Machinery," described by the Sub-Committee as an exhaustive discussion of the design of dynamo electric machinery, with the details, both theoretical and practical, of successful commercial designs and their progressive development in the past decade; of especial value as a reference work for the designer of modern direct-current and alternating-current dynamo electric machinery.

No. 2719.—The Edward Longstreth Medal of Merit to Prof. Henry J. M. Creighton, of Swarthmore, Pa., for his paper, entitled "The Deteriorating Action of Salt and Brine on Reinforced Concrete," described by the Sub-Committee as presenting the results of an original and scientific investigation in a matter of great practical importance.

No. 2720.—The Edward Longstreth Medal of Merit to Dr. J. B. Whitehead, of Baltimore, Md., for his paper, entitled "The Electric Strength of Air and Methods of Measuring High Voltage," described by the Sub-Committee as a clear exposition of the underlying principles of the phenomenon of the electric corona at high potentials, a *résumé* of the present methods of high-tension electrical measurement, and a full description of a new and noteworthy instrument—the Corona Voltmeter, invented by the writer—and its application to important problems in modern electrical engineering.

GEORGE A. HOADLEY,
Acting Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, March 7, 1918, at 8 o'clock, with Dr. H. J. Creighton in the chair. The minutes of the previous meeting were read and approved.

Dr. G. A. Hoadley announced the program of the meetings of the Philadelphia Section, American Institute of Electrical Engineers, for the remainder of the academic year.

W. D. Bigelow, Ph.D., Chief Chemist, Research Laboratories, National Canners' Association, delivered an address on "Scientific Research in the Canning Industry." The characteristic features of commercial and domestic canning were outlined, and various problems in the canning industry were described, with their solution. The paper was discussed by Doctors Hoadley, Hawk, Bigelow, and others. A vote of thanks was extended to Doctor Bigelow, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, March 14, 1918, at 8 o'clock, with Dr. George A. Hoadley, acting secretary of the Institute, in the chair.

Doctor Hoadley announced that, owing to the demands that government work made upon the scheduled speaker of the evening, Major Louis A. Fischer, he had found it impossible to prepare his paper on "The Importance of Gauging in the Manufacture of Munitions."

Doctor Hoadley then introduced Mr. F. H. Shelton as the speaker of the evening, who delivered a lecture on "Windmills, Picturesque and Historic, the Motors of the Past." The speaker described the various types of windmills as developed in the different countries and the growth of these types with time. The relation of the Newport (R. I.) arch tower ruin to its prototype, an English windmill, was brought out in a very interesting manner and the character and history of this ruin thus fixed. The lecture was illustrated by a large number of colored lantern slides from original photographs and old engravings.

After a brief discussion the thanks of the meeting were extended to Mr. Shelton.

Adjourned.

LIONEL F. LEVY,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, March 28, 1918, at 8 o'clock, with Dr. Harry F. Keller in the chair. The minutes of the previous meeting were approved as read.

George W. Littlehales, C.E., Hydrographic Engineer, U. S. Hydrographic Office, and Professor of Nautical Science, the George Washington University, Washington, D. C., delivered a lecture on "Oceanography." The history of the science of oceanography was outlined, and the methods and instruments of deep-sea research were described. An account was given of the depth and bulk of the ocean, the salinity, gases, temperature, pressure, compressibility, and viscosity of its waters, vision and penetration of light in its depths, distribution of atmospheric

pressure on the ocean, winds on its surface, oceanic movements and circulation, life in the ocean, and marine deposits on its bottom. The lecture was illustrated with lantern slides.

A vote of thanks was extended to Professor Littlehales, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 4, 1918, at 8 o'clock, with Dr. Gellert Alleman in the chair. The minutes of the previous meeting were read and approved.

Charles L. Reese, Ph.D., Chemical Director of E. I. du Pont de Nemours and Company, Wilmington, Del., delivered a lecture on "Explosives." A description was given of the ingredients, manufacture, and properties of black powder, brown powder, nitroglycerin, gun-cotton, explosive gelatine, explosive aromatic nitro compounds, other high explosives, and "permissible" explosives. The relationship between the explosives industry and the dye business was outlined. Laboratory and practical tests of explosives were shown by means of lantern slides, as were the uses of explosives in agriculture and engineering. The lecture was illustrated with specimens of raw materials, intermediate products, and finished explosives.

At the conclusion of the lecture the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mining and Metallurgical Section.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, April 11, 1918, at 8 o'clock, with Dr. Gellert Alleman in the chair. The minutes of the previous meeting were approved as read.

Arthur F. Taggart, E.M., Assistant Professor of Mining Engineering in the Sheffield Scientific School of Yale University, New Haven, Conn., delivered a lecture, entitled "An Explanation of the Flotation Process." A detailed account was given of the physico-chemical principles involved in froth flotation, their application in the concentration of sulphide ores of lead, zinc, and copper by flotation, the apparatus used, and the mode of operation. The lecture was illustrated with experiments and lantern slides.

The paper was discussed by Doctor Sadtler, Professors Dubois and Taggart, Drs. Carl Hering, Alleman, and Hepburn, and others. On motion of Dr. Walton Clark, seconded by Doctor Hering, a vote of thanks was extended to Professor Taggart, and the meeting then adjourned.

JOSEPH S. HEPBURN,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, April 10, 1918.)

RESIDENT.

MR. WILLIAM HENRY BRADSHAW, Chemist, 1241 Carpenter Street, Philadelphia, Pa.

NON-RESIDENT.

MR. PERCY WEDLAKE, Metallographist, Washington Steel and Ordnance Company, and for mail, 707 Portland Street, Congress Heights, D. C.

CHANGES OF ADDRESS.

MR. WILLIAM E. ALLEN, 109 South Forty-third Street, Philadelphia, Pa.
MR. FRANCIS H. GILPIN, 400 South Fifteenth Street, Philadelphia, Pa.
LIEUT. HAROLD GOODWIN, 3927 Locust Street, Philadelphia, Pa.
MR. L. J. R. HOLST, 6035 Carpenter Street, Philadelphia, Pa.
MR. CARY T. HUTCHINSON, 65 West Fifty-fourth Street, New York City, N. Y.
DR. ENOCH KARRER, 45th Engineers, Company A, Camp Meade, Md.
MR. JAMES MILLIKEN, 734 Fifteenth Street, N. W., Washington, D. C.
MR. WALTER PALMER, 105 West Twenty-third Street, Chester, Pa.
MR. ALEXANDER E. REOCH, Marconi Wireless Telegraph Company, Aldine, N. J.
MR. ALBERT L. WEBSTER, 112 East Fortieth Street, New York City, N. Y.

NECROLOGY.

Mr. Caleb Cresson, 1706 Pine Street, Philadelphia, Pa.
Mr. Rowland G. Hazard, Peacedale, R. I.

LIBRARY NOTES.

PURCHASES.

CROFT, TERRELL.—Electrical Machinery: Principles, Operation and Management. 1917.
EFFRONT, JEAN.—Biochemical Catalysts in Life and Industry. 1917.
EKBLAW, K. J. J.—Farm Concrete. 1917.
EMMONS, W. H.—Principles of Economic Geology. 1918.
Industrial Arts Index.—Annual Cumulation, vol. 5. 1917.
International Catalogue of Scientific Literature.—A—Mathematics, vol. 14. 1914.
JANSKY, C. M.—Theory and Operation of Direct-Current Machinery. 1917.
Reader's Guide to Periodical Literature, vol. 17. 1917.
Reader's Guide to Periodical Literature, Supplement, vol. 5. 1917.
ROBERTSON, T. B.—Physical Chemistry of the Proteins. 1918.

STERLING, F. W.—Internal-combustion Engine Manual. 1917.

STOKES, RALPH, and Others.—Text-book of Rand Metallurgical Practice, 2 vols. 1911.

TRAVERS, GUPTA, and HAY.—Some Compounds of Boron, Oxygen, and Hydrogen. 1916.

WAGNER, F. H.—Coal Gas Residuals. 1918.

WAGNER, J. B.—Seasoning of Wood. 1917.

GIFTS.

Allis-Chalmers Manufacturing Company, Bulletins of Agricultural Machinery; Air Brakes; Electrical Machinery; Flour Mill Machinery; Mining Machinery; Crushing and Cement Making Machinery; Prime Movers, Air Compressors, Hoists and Fans; Pumping Machinery and Hydraulic Turbines; and Saw Mill Machinery. Milwaukee, Wis., 1905–17. (From the Company.)

American Institute of Electrical Engineers, Year-Book, 1918. New York, 1918. (From the Institute.)

American Institute of Mining Engineers, Officers, Members, Rules, etc., March 1, 1918. New York, 1918. (From the Institute.)

American Railway Tool Foremen's Association, Year Book, 1917. Chicago, 1917. (From the Association.)

American Society of Civil Engineers, Transactions, vol. lxxxi, December, 1917. New York, 1917. (From the Society.)

American Telephone and Telegraph Company, Annual Report of the Directors for the Year Ending December 31, 1917. New York, 1918. (From the Company.)

Ashton Valve Company, Catalogue No. 12A. Boston, Mass., 1914. (From the Schade Valve Manufacturing Company, Philadelphia.)

Bird-Archer Company, A Practical Treatise upon Marine Boiler Deterioration; The Bird-Archer Treatments for Boilers; and Polarized Metallic Boiler Chemicals. New York, 1907, 1914, 1915. (From the Company.)

Broderick and Bascom Rope Company, Aerial Wire Rope Tramways. St. Louis, Mo., no date. (From the Company.)

Bryant Chucking Grinder Company, Bryant Production Book. Springfield, Vt., 1918. (From the Company.)

Buffalo, Rochester and Pittsburgh Railway Company, Thirty-third Annual Report for the Year Ending December 31, 1918. New York, 1918. (From the Company.)

Canada Department of Mines, Mines Branch, Preliminary Report on the Mineral Production of Canada During the Calendar Year 1917. Ottawa, 1918. (From the Department.)

Canadian Pacific Railway Company, Annual Report for the Fiscal Year Ended December 31, 1917. Montreal, 1918. (From the Company.)

Carlyle Johnson Machine Company, The Johnson Friction Clutch as Applied in Machine Building. Manchester, Conn., 1912. (From the Company.)

Carnegie Institution of Washington, Year Book No. 16, 1917. Washington, 1918. (From the Institution.)

Channon, H. Company, Catalogue No. 80, Machinery Tools, and Supplies. Chicago, 1916. (From the Company.)

Cleveland Automatic Machine Company, Thirty-one Articles by J. P. Brophy. Cleveland, Ohio, no date. (From the Company.)

Coburn Trolley Track Manufacturing Company, Catalogues Nos. G-3, 47, 48, 50, and 51. Holyoke, Mass., no dates. (From the Company.)

Colorado Iron Works Company, Catalogue No. 28-C, Continuous Filtration with the Portland Filter. Denver, Col., 1918. (From the Company.)

Cornell University, The Register, 1917–18. Ithaca, N. Y., 1918. (From the University.)

Cumulative Digest Corporation, Business Digest, July-September, 1917. New York, 1917. (From the Corporation.)

De la Vergne Machine Company, Ammonia Fittings Catalogue. New York, no date. (From the Company.)

Delaware College, Annual Catalogue, 1917–18. Newark, 1918. (From the College.)

Direct Separator Company, Steam and Oil Separators. Syracuse, N. Y., 1916. (From the Schade Valve Manufacturing Company, Philadelphia.)

Doak Gas Engine Company, Bulletins Nos. 12, 14, 31, and 51, of Doak Engines. Oakland, Calif. 1914–18. (From the Company.)

Florida State Geological Survey, First, Sixth, and Eighth Annual Reports, 1907–15. Tallahassee, 1908–16. (From the Survey.)

Gilbert and Barker Manufacturing Company, The Gilbert & Barker Process for Burning Fuel Oil Under Low Pressure. Springfield, Mass., 1918. (From the Company.)

Great Britain Meteorological Office, British Meteorological and Magnetic Year Book, 1914, part iv. London, 1917. (From the Office.)

Greenfield Tap and Die Corporation, Gun Tap Booklet. Greenfield, Mass., 1917. (From the Corporation.)

Hamilton Library Association, Report of the President for the Year 1917. Carlisle, Pa., 1918. (From the Association.)

Harrison Safety Boiler Works, Finding and Stopping Waste in Modern Boiler Rooms, vols. i and ii. Philadelphia, 1917–18. (From the Company.)

Hilles & Jones Company, Catalogue No. 8, of Machine Tools. Wilmington, Del., 1916. (From the Company.)

Hobart College, Catalogue, 1917–18. Geneva, N. Y., 1918. (From the College.)

Hoover Steel Ball Company, The Evolution of the Steel Ball Industry. Ann Arbor, Mich., no date. (From the Company.)

Hydro-Electric Power Commission of Ontario, Ninth Annual Report for the Year Ended October 31, 1916, vols. i, ii, and iii. Toronto, 1917. (From the Commission.)

Illinois State Geological Survey, Bulletins Nos. 23 and 30. Urbana, 1917. (From the Survey.)

Iron and Steel Institute, *The Journal*, vol. xcvi; and Carnegie Scholarship Memoirs, vol. viii. London, 1917. (From the Institute.)

Jonathan Bartley Crucible Company, Crucibles and other Graphite Productions for Foundry Use. Trenton, N. J., 1909. (From the Company.)

Kearney & Trecker Company, Cataolgue No. 20, Milwaukee Milling Machines. Milwaukee, Wis., no date. (From the Company.)

Keystone Driller Company, Blast Hole Drilling with Keystone Cable Drills. Beaver Falls, Pa., 1915. (From the Company.)

Lewis and Roth Company, Bulletin No. 21, Disconnecting Switches. Philadelphia, no date. (From the Company.)

Link-Belt Company, Book No. 270, Wagon and Truck Loaders. Philadelphia, 1917. (From the Company.)

Little Falls, N. Y., Board of Public Works, Twenty-third Annual Report, 1917. Little Falls, 1917. (From the Board.)

Mathews Gravity Carrier Company, Catalogues of Brick, Roller, and Lumber Conveyers. Ellwood City, Pa., no dates. (From the Company.)

Monarch Engineering and Manufacturing Company, Foundry Catalogue of Melting Furnaces. Baltimore, Md., no date. (From the Company.)

Music Trades Company, Piano and Organ Purchaser's Guide, Twenty-second Annual Edition. New York, 1918. (From the Company.)

National Pipe Bending Company, Catalogue Fifty-two, Direct Contact Feed-water Heaters. New Haven, Conn., 1916. (From the Company.)

Northampton, Mass., Water Commissioners, Forty-seventh Annual Report for the Year Ending November 30, 1917. Northampton, 1917. (From the Commissioners.)

Oneida National Chuck Company, Catalogue of National Chucks. Oneida, N. Y., 1918. (From the Company.)

Open Coil Heater and Purifier Company, The Stickle Open Coil Feed-water Heaters; and Steam Traps and Vacuum Heating Specialties. Indianapolis, Ind., no dates. (From the Schade Valve Manufacturing Company, Philadelphia.)

Pennsylvania Committee of Public Safety, Outline of Departmental Activities. Harrisburg, 1917. (From the Committee.)

Pennsylvania Department of Fisheries, Report, 1915. Harrisburg, 1916. (From the State Librarian.)

Pennsylvania Department of Internal Affairs, Bureau of Railways, Annual Report for the Year Ending June 30, 1916. Harrisburg, 1917. (From the State Librarian.)

Pennsylvania Insurance Commissioner, Forty-fourth Annual Report, 1916, part i, Fire and Marine Insurance. Harrisburg, 1917. (From the State Librarian.)

Pennsylvania Railroad Company, Record of Transportation Lines for the Year Ending December 31, 1917. Philadelphia, 1918. (From the Company.)

Philadelphia Department of City Transit, Annual Report for the Year Ending December 31, 1916. Philadelphia, 1917. (From the Department.)

Polytechnic Institute, Catalogue of the College of Engineering, 1918–19. Brooklyn, N. Y., 1918. (From the Institute.)

Providence Public Library, Fortieth Annual Report for the Year Ending December 31, 1917. Providence, R. I., 1918. (From the Library.)

S. K. F. Ball Bearing Company, Ball Bearings for Paper and Pulp Mill Machinery. Hartford, Conn., 1918. (From the Company.)

Schade Valve Manufacturing Company, The Divide Separator; and Catalogue No. 3-A, Steam Specialties. Philadelphia, no dates. (From the Company.)

Staffordshire Iron and Steel Institute, Proceedings, 1916–17, vol. xxxii. Stourbridge, 1917. (From the Institute.)

St. Louis University, Catalogue, 1918–19. St. Louis, Mo., 1918. (From the University.)

Taylor Instrument Companies, H. and M. Division, The Control of Temperature. Rochester, N. Y., 1917. (From the Companies.)

Truscon Steel Company, Standardized Structures Built with Standard Stock Units. Youngstown, Ohio, no date. (From the Company.)

Virginia Geological Survey, Bulletin No. XV-A, Tin Deposits Near Irish Creek, Virginia. Charlottesville, 1918. (From the Survey.)

United States Brewers' Association, Year Book, 1917. New York, 1918. (From the Association.)

University of Cincinnati, Publications of the Cincinnati Observatory, No. 18—Part iii, Catalogue of Proper Motion Stars. Cincinnati, Ohio, 1917. (From the University.)

U. S. Commissioner of Education, Report for the Year Ended June 30, 1917, vols. i and ii. Washington, 1917. (From the Commissioner.)

U. S. Reclamation Service, Sixteenth Annual Report, 1916–17. Washington, 1917. (From the Service.)

U. S. War Department, Report of the Tests of Metals and Other Materials Made at the Watertown Arsenal, Massachusetts, for the Years 1915, 1916. Washington, 1917. (From the Department.)

Yuba Manufacturing Company, Booklets of Models 12-20 and 20-35 Ball Tread Tractors. San Francisco, Calif., no dates. (From the Company.)

BOOK NOTICES.

CHEMICAL FRENCH: An Introduction to the Study of French Chemical Literature, by Maurice L. Dolt, Ph.D., North Dakota Agricultural College. Easton, Pa., The Chemical Publishing Company, 1918. 398 pages and table of contents, 8vo. Price, $3.

In view of the abundance of French literature of all types at present in this country, there would seem to be but a limited field for this book. Only favorable criticism can be made of it, for it contains a large amount of interesting information. After some preliminary matters, relating to the grammatical structure of the French language, essays on many important topics in chemistry are given, and about one hundred and sixty pages of reprints of important articles, originally appearing in that language. Among these are articles by Berthelot, Grignard, Pasteur, and Curie. A useful table of the accidence of the principal irregular verbs, and a small vocabulary close the volume. There is no index, but this is hardly needed in such a book.

HENRY LEFFMANN.

STEAM BOILERS: A PRACTICAL AND AUTHORITATIVE DISCUSSION OF BOILER DESIGN AND CONSTRUCTION, AND THE DEVELOPMENT OF MODERN TYPES. Revised by Robert H. Kuss, M.E. Chicago, American Technical Society, 1917. 82 pages, 74 illustrations, 8vo., cloth. Price, $1.

There is a demand among many engineers and designers for reference works describing approved practice in the simplest possible terms and devoid of difficult analytical discussions. Among books appearing in recent years that meet this requirement, though written for a different class of users, are the beautifully illustrated and well-executed texts issued by some of our correspondence schools. The present volume is of this type. About fifty pages are devoted to the elements of design, with illustrations of typical details. The remainder of the work is essentially an album of standard types of boilers in common use, with brief descriptions and notes. It is a compact, typographically well-executed book which will appeal to those who desire condensed information on the structural features of commonly used types of boilers.

LUCIEN E. PICOLET.

PUBLICATIONS RECEIVED.

The Physical Chemistry of the Proteins, by T. Brailsford Robertson, Ph.D., D.Sc. 483 pages, 8vo. New York, Longmans, Green & Co., 1918. Price, $5.

Mechanical Laboratory Methods: The Testing of Instruments and Machines in the Mechanical Engineering Laboratory and in Practice, by Julian C. Smallwood, M.E. Second edition, revised and enlarged. 399 pages, illustrations, 12mo. New York, D. Van Nostrand Company, 1918. Price, $3.

The Chemist's Pocket Manual: A Practical Hand-book Containing Tables, Formulas, Calculations, Information, Physical, and Analytical Methods for the Use of Chemists, Chemical Engineers, Assayers, Metallurgists, Manufacturers, and Students, by Richard K. Meade, M.S. Third edition, 530 pages, illustrations, 16mo. Easton, Pa., The Chemical Publishing Company, 1918. Price, $3.50.

A Short Hand-book of Oil Analysis, by Augustus H. Gill, S.B., Ph.D. Revised eighth edition, 209 pages, illustrations, 12mo. Philadelphia, J. B. Lippincott Company, 1918. Price, $2.50.

Theories of Energy, by Horace Perry. 231 pages, 12mo. New York, G. P. Putnam's Sons, 1918. Price, $1.75.

Van Nostrand's Chemical Annual: A Hand-book of Useful Data for Analytical, Manufacturing, and Investigating Chemists, Chemical Engineers, and Students. Fourth issue, 1918, thoroughly revised and enlarged, edited by John C. Olsen, A.M., Ph.D. 778 pages, portrait, 12mo. New York, D. Van Nostrand Company, 1918. Price, $3.

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